Contents—Sept. 1948

Volume XXIX No. 9

ARCHIVES OF PHYSICAL MEDICINE
(Formerly Archives of Physical Therapy)
30 North Michigan Avenue, Chicago 2, Illinois

Original contributions, exchanges and books for review should be forwarded to the Editorial Office. All business matters including advertising should be handled through the Executive Office, 30 N. Michigan Ave., Chicago 2, Illinois. The statements in the manuscripts published in the ARCHIVES OF PHYSICAL MEDICINE are made solely on the responsibility of the author. The American Congress of Physical Medicine does not assume any responsibility for statements contained therein. Manuscripts accepted for publication in ARCHIVES OF PHYSICAL MEDICINE are for exclusive publication and may not be published elsewhere.

OFFICERS

American Congress of Physical Medicine

H. WORLEY KENDELL, M.D.,
Chicago, President.
O. LEONARD HUDDLESTON, M.D.,
Los Angeles, President-Elect.
EARL C. ELKINS, M.D.,
Rochester, Minn., First Vice-President.
ARTHUR L. WATKINS, M.D.,
Boston, Second Vice-President.
ROBERT L. BENNETT, M.D.,
Warm Springs, Ga., Third Vice-President.
WALTER M. SOLOMON, M.D.,
Cleveland, Fourth Vice-President.
WILLIAM B. SNOW, M.D.,
New York, N. Y., Fifth Vice-President.
RICHARD KOVACS, M.D.,
New York, N. Y., Secretary.
JOHN S. COULTER, M.D.,
Chicago, Treasurer.
WALTER J. ZEITER, M.D.,
Cleveland, Executive Director.
MARION G. SMITH, B.S.,
Chicago, Executive Secretary.

EXECUTIVE COUNCIL

Walter S. McClellan, M.D., Saratoga Springs, N. Y., *Chairman.*
Norman E. Titus, M.D., Coatesville, Pa., *Secretary.*
William Bierman, M.D., New York, N. Y.
John S. Coulter, M.D., Chicago.
James C. Elsom, M.D., Madison, Wisconsin.
Frank H. Ewerhardt, M.D., St. Louis, Mo.
Roy W. Fouts, M.D., Omaha, Nebraska.
Kristian G. Hansson, M.D., New York, N. Y.
John Severy Hibben, M.D., Pasadena.
Abraham R. Hollender, M.D., Miami Beach, Fla.
Miland E. Knapp, M.D., Minneapolis, Minn.
Disraeli Kobak, M.D., Chicago.
Frank H. Krusen, M.D., Rochester, Minn.
Fred. B. Moor, M.D., Los Angeles.
Nathan H. Polmer, M.D., New Orleans.
William H. Schmidt, M.D., Philadelphia.
Frederick L. Wahrer, M.D., Marshalltown, Ia.
H. Worley Kendell, M.D., Chicago, Ex-Officio.

EDITOR EMERITUS

Disraeli Kobak, M.D.,
Chicago.

Subscription — In the United States, its possessions, and Mexico, $7.00 yearly; Canada, $8.00; elsewhere, $10.00 the year.

Advertising rates on application. All advertising copy subject to acceptance by publication committee.

Published monthly at Chicago, Illinois, by American Congress of Physical Medicine.

Entered as Second Class Matter, February 15, 1945, at the Post Office at Chicago, Illinois, under the Act of March 3, 1879.

ORIGINAL ARTICLES

Importance of Current Form and Frequency in Electrical Stimulation of Muscles. Studies in Retardation of Muscle Atrophy in the Dog. A. J. Kosman, Ph. D.; S. L. Osborne, Ph.D., and A. C. Ivy, M.D., Ph.D. 559

Atrophy of Disuse. A Definition. Arthur S. Abramson, M.D. 562

Newer Concepts of Electrodiagnosis in Peripheral Nerve Injuries. Alex J. Arieff, M.D. 571

Neurologic Aspects of Spinal Cord Injuries. Lewis J. Pollock, M.D. 579

The Effects of Diathermy on the Flow of Blood in the Extremities. An Experimental and Clinical Study. Khalil G. Wakim, M.D., Ph.D.; Jerome W. Gersten, M.D.; Julia F. Herrick, Ph.D.; Earl C. Elkins, M.D., and Frank H. Krusen, M.D. With Technical Assistance of A. N. Porter 583

Medical News 594

Editorials 595

Book Reviews 602

Physical Medicine Abstracts 606

EDITOR OF THE MONTH

EARL C. ELKINS, M.D.
Rochester, Minnesota

Printed in U.S.A.

The Treatment of

SCLERODERMA AND VASOSPASTIC CONDITIONS OF THE EXTREMITIES, INCLUDING RAYNAUD'S DISEASE AND CHRONIC ULCER

THIS 16 MM. SILENT KODACHROME MOTION PICTURE (running time, 15 minutes), shows the technic of administering Mecholyl Chloride by the method of ion transfer (iontophoresis) and the results of treatment in chronic ulcer and scleroderma. The film will be loaned to interested physicians on request. Applications for loan will be filled as quickly as prints of the film are available. Please enter your request as far in advance as possible.

Address communications regarding film to Merck & Co., Inc., Dept. RA ADV., Rahway, N. J.

Mecholyl Chloride has been accepted by the Council on Pharmacy and Chemistry. Its administration by ion transfer (iontophoresis) was found to increase blood flow five times in the forearm skin and six and one-half times in the leg skin.

MECHOLYL® CHLORIDE

METHACHOLINE CHLORIDE U.S.P. MERCK

An effective parasympathetic stimulant

COUNCIL ACCEPTED

MERCK & CO., Inc. RAHWAY, N. J.

Manufacturing Chemists

In Canada: Merck & Co., Ltd. Montreal, Que.

MERCK MERCK

IMPORTANCE OF CURRENT FORM AND FREQUENCY IN ELECTRICAL STIMULATION OF MUSCLES

Studies in Retardation of Muscle Atrophy in the Dog *

A. J. KOSMAN, Ph.D.
S. L. OSBORNE, Ph.D.
and
A. C. IVY, M.D., Ph.D.‡

CHICAGO, ILL.

In previous publications,[1] we presented evidence that a sinusoidal alternating current of appropriate frequency (25 cycles per second) was more effective than other currents in common clinical usage in maintaining the weight and strength of denervated rat muscles. Although the use of rats for such experimentation has the considerable advantage of a rate of denervation atrophy rapid enough to produce the most marked losses in muscle weight and strength in short periods of time (two to four weeks), the use of a less genetic homogenous animal with a slower rate of atrophy and on which the painfulness of electrical stimulation could be accurately determined, would provide, perhaps, a more suitable comparison with man. For these reasons, the effects of daily electrical stimulation over long periods of time upon the course of atrophy of the denervated gastrocnemius-soleus muscles of the dog were studied.

Methods

As a preliminary procedure it was necessary to determine whether the right and left gastrocnemius-soleus muscles of the dog were of the same mass in any given animal when (1) the innervation of these muscles was intact and (2) at various times following the bilateral destruction of their innervation.

Thirty-four normal dogs adjusted to laboratory conditions for a period of two weeks were killed and the wet weights of their gastrocnemius-soleus muscles immediately determined. In a second group of 28 dogs a large section of the sciatic nerve was removed bilaterally. These animals were sacrificed at periods of three, six or nine months following the denervation and the wet weights of the gastrocnemius-soleus muscles determined. A third group of 23 dogs constituted the treated group. These animals were also subjected to an extensive bilateral section of the sciatic nerve and then the gastrocnemius-soleus muscles of one limb (either left or right) were stimulated twice daily for five minutes with a modulated sinusoidal current with a carrier frequency of 25 cycles per second. The carrier frequency was sinusoidally modulated at a rate of 25 cycles per second. The treatments extended over a period of three, six or nine months, and at the end of these times the animals were killed and both treated and untreated muscles were weighed.

The dogs were neither anesthetized nor restrained in any fashion while they were being stimulated. The intensity of the applied current was adjusted to a value which the dog accepted quietly and with no discernible signs of discomfort. Upon any signs of unrest, the current intensity was decreased until the animal was quiet again. After several days the limits of tolerance for any particular animal were well established and the strength of the stimulating current thus determined was used throughout the

From the Departments of Physiology and Physical Medicine, Northwestern University Medical School.
*Aided in part by a grant from National Foundation of Infantile Paralysis.
‡Now at University of Illinois, Chicago.
1. (*a*) Kosman, A. J.; Osborne, S. L., and Ivy, A. C.: The Effect of Various Types of Electrical Stimulation and of Frequency of Stimulation Upon Muscle Atrophy in the Rat, Federation Proc., 4:11, 1945; (*b*) The Comparative Effectiveness of Various Electrical Currents in Preventing Muscle Atrophy in the Rat, Arch. Phys. Med. 28:7, 1947.

experiment. It was not at all unusual for the dogs to sleep during the period of stimulation. The technic of stimulation was similar to that used clinically — a large dispersive electrode on the abdomen and the smaller stimulating electrode placed over the treated muscle.

When the period of denervation exceeded three months, periodic exploratory operations were performed for any possible reinnervation and any regenerating nervous tissue, if present, was removed. At sacrifice no neurotization of any of the muscles had occurred.

Results

Weights of Normal Muscles. — There are no significant differences in weight between the left and right gastrocnemius-soleus muscles (table 1). The

TABLE 1. — *Weights of Left and Right Normal Gastrocnemius-Soleus Muscles.*

No. of Dogs	Mean Weight in Grams Left	Right	
34	29.986	29.600	
	$t = 1.24$	$r = 0.98$	

correlation of these muscle weights in the same animal is quite high ($r = 0.98$). An attempt was made to correlate body weight with muscle weights and thus establish a reference point by which the degree of atrophy following various intervals of denervation could be approximated. However, in the dog the correlation between the weight of the gastrocemius-soleus muscles and the body weight is rather poor ($r = 0.49$), and any approximation of the extent of atrophy by this method would be meaningless.

Weights of Untreated Denervated Muscles. — As in the case of normally innervated muscles, the differences in weight between left and right muscles in any particular animal three, six and nine months after denervation are insignificant (table 2). The loss of weight following the bilateral denerva-

TABLE 2. — *Mean Weights of Untreated Denervated Left and Right Gastrocnemius-Soleus Muscles.*

Duration of Denervation	No. og Dogs	Mean Weight (Gm.) Left	Right	
3 Months	10	20.362	20.533	$t = 0.192$
				$r = 0.82$
6 Months	12	19.506	18.911	$t = 1.13$
				$r = 0.95$
9 Months	6	15.328	14.859	$t = 0.443$
				$r = 0.82$

tion proceeds at essentially the same rate for the muscles of both limbs.

Weights of Stimulated and Untreated Muscles. — It is clear from an examination of table 3 and the chart that daily electrical stimulation effectively retarded the atrophy of denervation. Three months after denervation the treated muscles were 19.5 per cent heavier than their untreated controls. After

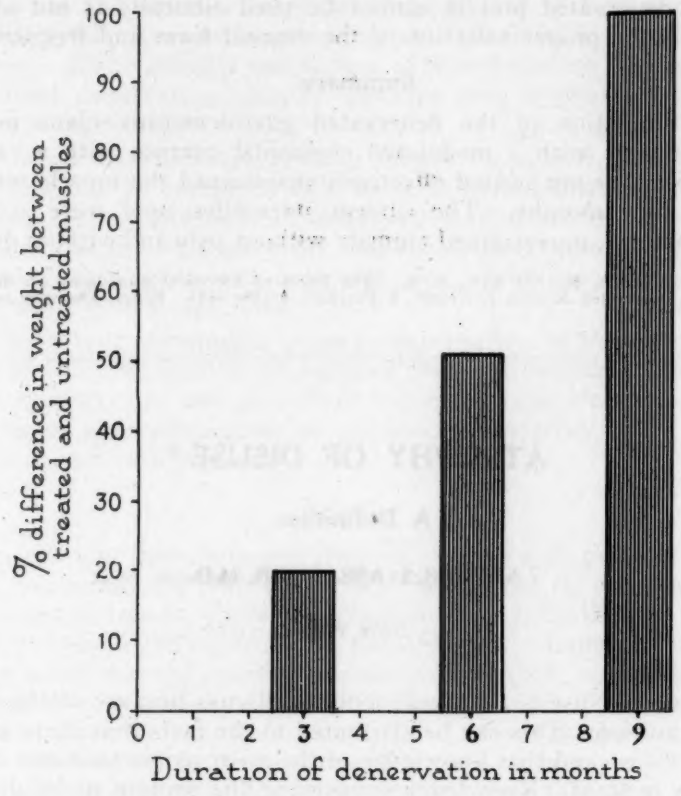
TABLE 3. — *Mean Weights of Treated and Untreated Gastrocnemius-Soleus Muscles.*

Duration of Denervation	No. of Dogs	Mean Weight (Gm.) Treated	Untreated	% Diff.	
3 Months	9	22.302	18.672	19.5	$t = 5.29$*
6 Months	7	19.569	12 732	53.5	$t = 4.35$*
9 Months	7	22.770	11.799	93.6	$t = 5.83$*

* Significant on the 1 per cent level of probability.

six months this difference had increased to 53.5 per cent, and at nine months the margin of difference between treated and untreated muscles had widened to 39.6 per cent. Thus, the differences in weight between treated and un-

treated muscles becomes progressively greater the longer the period of denervation.



Comment

Although ample evidence has been accumulated to show that denervation atrophy can be effectively retarded by electrical stimulation,[2] from a practical point of view it is important to know whether similar results can be obtained under conditions more closely resembling those found clinically. A *sine qua non* of the effectiveness of electrical stimulation is that it produce vigorous contractions of the muscle,[2] and in a previous communication[1b] we pointed out that not all currents are equally capable of fulfilling this requirement at current intensities which could conceivably be tolerated by the average patient. In the denervated gastrocnemius muscle of the rat we found that a modulated sinusoidal current with a carrier frequency of 25 cycles per second developed the greatest muscle tension at the lowest current intensities, and was also the most effective current in the retardation of its atrophy.

In these previous experiments it was difficult to evaluate the painfulness of the stimulating current. These difficulties are overcome in the present studies and without question a modulated sinusoidal current with a carrier frequency of 25 cycles per second can elicit strong contractions of the dener-

2. (*a*) Fischer, E.: Effect of Faradic and Galvanic Stimulation Upon Course of Atrophy in Denervated Skeletal Muscles, Am. J. Physiol. **127**:605, 1939; (*b*) Guttman, E., and Guttmann, L.: Effect of Electrotherapy on Denervated Muscles in Rabbits, Lancet **1**:169, 1942. (*c*) Solandt, D. Y.; De Lury, D.B., and Hunter, J.: Effect of Electrical Stimulation on Atrophy of Denervated Skeletal Muscle, Arch. Neurol. & Psychiat. **49**:802, 1943. (*d*) Hines, H. M.; Thomson, J. B., and Lazere, B.: Physiological Basis for Treatment of Paralyzed Muscle, Arch. Phys. Therapy **24**:69, 1943. (*e*) Grodins, F. S.; Osborne, S. L.; Johnson, F. R.; Arana, S., and Ivy, A. C.: The Effect of Appropriate Electrical Stimulation on Atrophy of Denervated Skeletal Muscle on the Rat, Am. J. Physiol. **142**:222, 1945. (*f*) Eccles, J. C.: Investigations on Muscle Atrophies Arising from Disuse and Tenotomy, J. Physiol. **103**:253, 1944.

vated muscles and maintain its weight over a period of nine months at current intensities easily and comfortably tolerated by the dogs.

Statements[3] that current intensities sufficient to produce vigorous contractions of denervated muscle cannot be used clinically is not at all true when there is the proper selection of the current form and frequency.

Summary

Daily stimulation of the denervated gastrocnemius-soleus muscles of twenty-three dogs with a modulated sinusoidal current with a carrier frequency of 25 cycles per second effectively maintained the muscle weight over a period of nine months. The current intensities used were accepted by the unanesthetized, unrestrained animals without pain and without discomfort.

3. Doupe, J.; Barnes, R., and Kerr, A. S.: The Effect of Electrical Stimulation on the Circulation and Recovery of Denervated Muscle, J. Neurol. & Psychiat. 6:136, 1943. Hines, Thomson and Lazere.2d.

ATROPHY OF DISUSE *

A Definition

ARTHUR S. ABRAMSON, M.D.

NEW YORK

Atrophy of disuse is a difficult topic to discuss because of the lack of an adequate definition. This can be attributed to the facts that there exist many concepts of disuse and that knowledge of the microscopic anatomic and chemical changes is scant. Knowledge concerning the protein molecular changes occurring in the various types of atrophy is still less complete. One need only to examine one or two definitions that have found their way into the literature to realize their weaknesses and to highlight the points at which present day knowledge fails in an attempt to understand the process of disuse.

Chor and Dolkart felt that in skeletal muscle disuse produced a wasting of muscle tissue due solely to the curtailment of its specific function of contraction. They further stated that this wasting occurred without any accompanying disturbances of nerve and blood supply.[1] This definition would exclude completely the atrophy occurring in denervation. This seems paradoxic, since denervation itself curtails the specific function of contraction and creates perhaps the most favorable conditions for disuse. It is obvious that the stumbling block here is that the vague concept of "neurotrophic influence" has again interjected itself into the argument. An attempt will be made to show that such an influence plays a rather insignificant role in atrophies resulting from diverse sources and that the lack of function is the determining factor in decrease in size of tissues that are not being used.

A much more general, but at the same time more acceptable, definition is that expressed by Carey and his co-workers.[2] In their opinion, parts of the living body increase and decrease in size in proportion to the functional

* Read at the Eastern Section Meeting of the American Congress of Physical Medicine, Philadelphia, Pennsylvania, April 10, 1948.

* From the Department of Physical Medicine, Veterans Administration Hospital, Bronx, N. Y. Published with permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or conclusions drawn by the authors.

1. Chor, H., and Dolkart, R. E.: Am. J. Physiol. 117:626, 1936.

2. Carey, E. J.; Haushalter, E.; Massopust, L. D.; Gakofuld, F.; Lynch, J.; Tabat, D., and Socoloff, E.: Proc. Soc. Exper. Biol. & Med. 64:193, 1947.

demand or use. They were careful to explain that the essential underlying cause of the changes has remained an elusive one.

At this point it seems logical to determine what the characteristics of denervation are and whether these can be attributed to loss of neurotrophic control to determine to what degree they are influential in producing shrinkage of tissue. If the atrophy due to loss of function alone can be subtracted from the total denervation atrophy, perhaps then a clearer picture of the role of disuse will emerge.

Denervation has its most striking effects on muscle, and the atrophy occurring here will be compared with those in immobilization, tenotomy, inanition, cord section and afferent denervation of a section of the cord, as described by Tower.[3] Although all tissues probably shrink when removed from function, this paper will deal with that shrinkage occurring only in muscle, nervous system and bone.

Four important phenomena occur in denervation of the muscle.[4] These consist in atrophy, fibrillation, changes in chemical excitability to such substances as acetylcholine and potassium and changes in electrical excitability resulting in an altered response to galvanic stimulation and a diminished response to faradic stimulation.

Atrophy

In denervation, Lipschutz and Audova showed a 40 per cent loss of dry weight in two weeks, 50 per cent in four weeks and 60 per cent in twelve weeks.[5] Seven to ten days after denervation occurs, fibrillation sets in, and it remains as long as any contractile tissue is left.[6] Langley and Kato expressed the belief that the atrophy was due to overwork, caused by the ceaseless, haphazard contraction of the individual muscle fibers.[7] Tower supported this view and cited Lorenz, who demonstrated an occupational atrophy, due to overwork, occurring in certain muscle groups in laborers.[8] Solandt felt that the tension produced by fibrillation is much less than that produced by normal muscles.[4] In albino rats quinidine reduces or abolishes fibrillation without greatly affecting the rate of atrophy.[9] Large doses of atropine will produce a reduction in shrinkage without affecting the fibrillation.[4] This was confirmed by Hines and Wehrmachter, who found that fibrillation enhancing drugs, such as potassium chloride and neostigmine, did not accelerate the rate of atrophy. They pointed out, also that electrical stimulation had no significant effect on fibrillation but greatly retarded the rate of atrophy.[10] Thus, there is little evidence that fibrillation has any influence in producing atrophy.

In tenotomy, there is no fibrillation, but the rate of atrophy is the same as in denervation,[5] (fig. 1) or only slightly less.[11] Tenotomy plus denervation in the same muscle produces the same rate of atrophy as in denervation alone.[11] Spontaneous union of the tendon, which is difficult to prevent, results in a rapid recovery of size and strength of the muscle.[12] Heidenhain and Fick, cited by Lipschutz and Audova, showed that heat production of the muscle decreases when the load is smaller. The work done in tenotomy is decreased, and thus the loss of weight after tenotomy would seem to be purely an instance of atrophy by decreased activity.[5]

3. Tower, S. S.: J. Comp. Neurol. 67:241, 1937.
4. Solandt, D. Y.: J. A. M. A. 120:511, 1942.
5. Lipschutz, A., and Audova, A.: J. Physiol. 55:300, 1921.
6. Tower, S. S.: Physiol. Rev. 19:48, 1939.
7. Langley, J. M., and Kato, T.: J. Physiol. 49:432, 1915.
8. Tower, S. S.: Arch. Neurol. and Psychiat. 42:219, 1939.
9. Solandt, D. Y., and Magladery, J. W.: Brain 63:255, 1940.
10. Hines, H. M., and Wehrmachter, W. H.: J. Iowa M. Soc. 34:142, 1944.
11. Hines, H. M., and Knowlton, G. C.: Am. J. Physiol. 128:97, 1939.
12. Knowlton, G. C., and Hines, H. M.: Am. J. Physiol. 128:521, 1940.

In immobilization atrophy the rate approaches that of denervation, according to Hines and Whermachter.[10] But Solandt[4] and Chor and Dolkart[1] found a remission in the fourth week which they could not explain (fig. 1). Knowlton and Hines have suggested that postural and gross movement re-

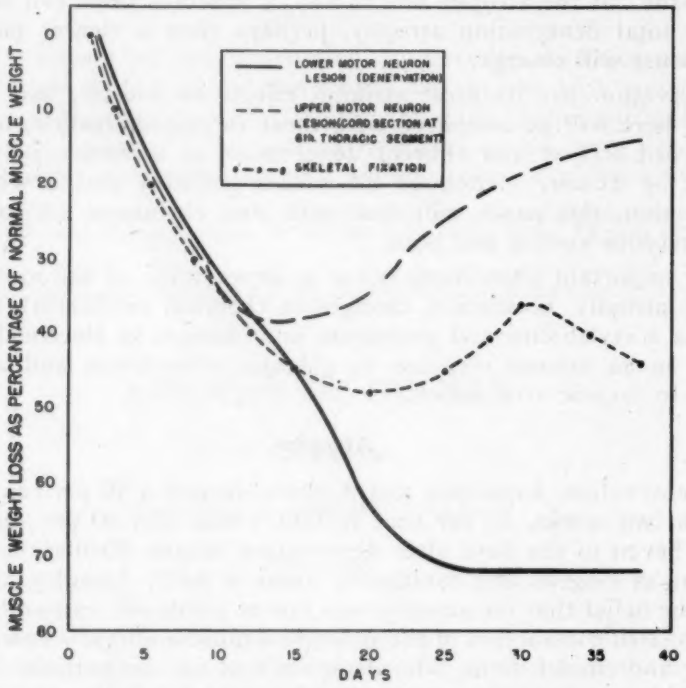


Fig. 1. — Atrophy of disuse in skeletal muscle. The rates in tenotomy and in the Tower spinal preparation correspond closely to that of denervation. (Adapted from Solandt.)

flexes have an enhancing influence on physiologic stretch.[12] Since such reflexes seem inevitable, even in a limb immobilized in plaster, the remission might be explained on this basis. Immobilization fails to accelerate the rate of atrophy in denervation, thus suggesting that denervation alone affords conditions for maximal rates of atrophy.[10]

In cord section, again, there is no fibrillation, since the lower motor neuron is intact. Here, too, the rate of atrophy for the first two weeks is of the same order as that of denervation. But then recovery occurs until the muscle is almost normal in bulk.[4] (fig. 1). The initial period of atrophy corresponds to that of the so-called spinal shock in human beings. During this time there is complete flaccidity, as in denervation, but then mass reflexes set in and violet mass muscle movements occur. These contractions are undoubtedly the stimulus to muscle recovery. It has been shown by Burn and co-workers,[13] Cannon and Haimovici,[14] Stavraky[15] and others that sensitization of the partially isolated spinal neuron to neurohumors, such as acetylcholine and epinephrine, can occur after a short period of neuron silence. Here, again, is a possible explanation for an observed phenomenon.

In inanition atrophy, Carey concluded from morphologic studies, there is a rapid denervation or uprooting of motor nerves, which results in a structural detachment of a portion of the motor fibers.[16] Hines, Thomson

13. Burn, J. H.: Physiol. Rev. 25:377, 1945.
14. Cannon, W. B., and Haimovici, H.: Am. J. Physiol. 126:731, 1936.
15. Stavraky, G. W.: Am. J. Physiol. 150:37, 1947.
16. Carey, E. J.: Proc. Soc. Exper. Biol. & Med. 50:155, 1942.

and Lazere found no evidence that prolonged acute inanition resulted in functional denervation, since no fibrillation occurred, there was no contracture response to acetylcholine, the same amount of tension could be produced per unit weight in the starved as in the normal animal and, finally, nerve regeneration with functional contact with the muscle occurred as well in the unfed as in the fed animal.[17] Hines and Wehrmachter showed that the atrophy paralleled the loss in body weight.[10]

Tower denervated a section of the cord by transecting the cord above and below and cutting all dorsal roots.[6] In this way she felt that all afferent pathways were removed. Muscle innervation remained intact, and no fibrillation occurred.[18] The muscle was completely quiet, except for short-lived bursts of activity occurring every week or so. She felt that this was due to direct stimulation of the cord and that its influence in preventing atrophy was negligible. The rate of atrophy was of the same order as in denervation (fig. 1). Because little or no spontaneous activity occurred and because there was no functional, transsynaptic degeneration with resulting fibrillation, the quiescence seemed real, and she and her co-workers concluded that this was a true atrophy of disuse.[18]

Changes in Chemical and Electrical Excitability

Only in denervation do changes occur. Denny-Brown and Pennypacker suggested that the fibrillation was due to increased sensitivity of the muscle to acetylcholine.[19] Recent experiments by Magladery and Solandt showed that this sensitivity is the response of muscle to the normal quantities of acetylcholine and potassium found in the body fluids.[4] However, in adult albino rats, Hines showed that fibrillation disappeared but hypersensitivity remained for as long as thirty-five days after the nerve regenerated.[20] The altered response to galvanic current and the diminished response to faradic current occur after a few days. During this period, preceding wallerian degeneration, the strength duration curve may even fall, followed by a gradual rise. Reid showed that while in disuse the curve had the characteristics of normal muscle with chronaxies in the vicinity of 0.08 microfarad, in denervation the chronaxie rose to 0.64 microfarad.[21]

In 1938 Solandt and Scott suggested that the reaction of degeneration may be linked to the chemical hypersensitivity.[22]

Histologic, Chemical and Functional Changes

In denervation, muscle fibers shrink and increases in fibrous tissue occur.[23] There is also an increase in subsarcolemmal nuclei.[24] These changes are believed to be absolute. Altschul and Tower have expressed the opinion that actual metaplasia to collagen occurs.[25] Altschul [25] stated the belief that the subsarcolemmal nuclei themselves become fibroblasts, as against the opinion of Gutmann and Young,[24a] that the increase in nuclei is actually due to the proliferation of fibroblasts themselves. Gutmann and Young also showed that after years the whole muscle cell splits up in short spindle-shaped fragments, or into spherical or ovoid sections, and is finally completely replaced by fibrous tissue.[24a] In disuse, Tower found atrophy of the muscle cell and

17. Hines, H. M.; Thomson, J. D., and Lazere, B.: Am. J. Physiol. 140:115, 1942.
18. Tower, S. S.; Bodian, D., and Howe, H.: J. Neurophysiol. 4:398, 1941.
19. Denny-Brown, D. E., and Pennypacker, J. B.: Brain 61:311, 1938.
20. Hines, H. M.: J. A. M. A. 120:515, 1942.
21. Reid, G.: M. J. Australia 2:165, 1941.
22. Solandt, D. Y., and Scott, J. W.: Proc. Sixteenth Internal. Physiol. Congress, Zurich, 1938.
23. Tower, S. S.: Am. J. Anat. 58:1, 1935.
24. (a) Gutmann, F., and Young, J. Z.: J. Anat. 78:15, 1944. (b) Tower.23
25. (a) Altschul, R.: Arch. Path. 34:982, 1942. (b) Tower.23

proliferation of the interstitial fibrous tissue. Others believe this increase of fibrous tissue to be relative. The increase of subsarcolemmal nuclei Tower felt to be relative. Their shape and staining qualities were different from those in denervation. The small cell and even polymorphonuclear infiltration observed in denervation were not observed in disuse.[21]

There are no significant changes in the water and nitrogen content in simple immobilization atrophy.[1] The relative proportions remain the same, since the quantitative decrease in protein content is associated with decrease in weight. According to Lipschutz and Audova, the relative water content is greater than normal in denervation, tenotomy and inanition atrophy.[5] There is also an increase in water-soluble substances which are the products of decomposition of the organic constituents of the living cell. In starvation, protein breakdown occurs without replacement and a negative nitrogen balance ensues. Thompson observed that there is uniformly a more marked loss of total body weight than would be expected from the loss of the immobilized limb alone.[26] Howard concluded that the total negative nitrogen balance in these cases cannot be due to disuse alone.[27]

It has been shown that weight loss in denervation proceeds to about 20 per cent without loss of strength per unit muscle cell phase; then progressive and severe loss of strength occurs.[12] There is also a severe loss in absolute strength in tenotomy, which, however, is reversible by spontaneous tendon repair. Inanition atrophy shows no loss of strength in the remaining muscle cell phase. For nine to eleven days at the beginning of denervation the loss of birefringence parallels weight loss in denervation but then, together with tension loss, outstrips it.[28] Electrical stimulation can decrease the rate of atrophy and to a lesser extent the rate of birefringence and tension loss.[29] Contractile power per unit weight parallels birefringence throughout atrophy at this time.[28] This is probably due to the fact that contraction in denervation fails to prevent damage to the ultrastructure of the muscle.

In summary, then, it can be said that atrophy in muscle parallels the loss of tension. This principle is widely accepted. It has been pointed out that passive stretching has no influence in preventing atrophy in denervation.[10] The most rapid and consistent rates of atrophy occur in denervation, tenotomy and in the Tower spinal preparation. In each of these cases the stretch reflexes are lost. In upper motor neuron lesions and in immobilization the stretch reflexes remain intact. Fibrillation and changes in chemical and electrical excitability seem to have little influence on atrophy. Chemical, anatomic and functional changes become more profound with greater and greater interference with the proper functioning of nervous pathways.

Thus, the stimulus which prevents atrophy can be attributed, within the present state of knowledge, to that tension produced by muscular contraction itself. The greater the interference with the mechanisms producing that tension, the more profound are the atrophy and the intrinsic muscle changes. The energy levels established by the chemical reactions associated with tension development may be necessary for the anabolic processes in muscles.[10] Denervation prevents a muscle which has lost considerable protein, because of wasting, from regaining this material during periods of subsequent feeding. Thus, the less the muscular contraction is used, the less will it be able to maintain muscle bulk. This has been expressed by Ayre[30] and Eccles,[31] who feel that contraction through the whole range is important. Ayre stated that

26. Thompson, T. C.: J. Bone & Joint Surg. 16:564, 1934.
27. Howard, J. E., and others: Bull. Johns Hopkins Hosp. 75:156, 1944.
28. Fischer, E.: Am. J. Physiol. 131:156, 1940.
29. Fischer, E.: Am. J. Physiol. 127:605, 1939.
30. Ayre, W. B.: Canad. M. Ass. J. 53:352, 1945.
31. Eccles, J. C.: M. J. Australia 2:160, 1941.

repeated voluntary tensing of the immobilized muscle is only partially successful in preventing atrophy.[30] Hill demonstrated that the energy of a contraction is not set free in an all-or-none outburst but continues to appear as the shortening progresses.[32] Shortening of muscle against a load may be even more effective, as pointed out by Heidenhain and Fick.[5] The lagging behind of birefringence and contractile strength in electrical stimulation of the denervated muscle may be due to the inability to produce isotonic contraction against a load by such means. These basic principles elaborated from a study of muscle atrophy seem to have universal application. The argument can be extended further into the nervous and skeletal systems.

Atrophy of Disuse in the Central Nervous System

When a limb is amputated, the anterior horn shrinks and may even disappear (Spatz, cited by Chor and Dolkart[1]). Chor and Dolkart immobilized the right upper extremities of monkeys for a year.[1] At the end of that time, they found no difference between the anterior horn cells of the two sides, and the peripheral nerves were also normal in appearance. Spatz called the changes in amputation axonal chromatolysis. These changes consist in displacement of the nucleus to the axon hillock and clumping of the Nissl bodies in that locality, with a paling of the remaining cytoplasm. These changes are attributed to axon injury. It is more obvious that in immobilization nerve contact with the muscle exists, permitting the transmission of postural and gross movement reflexes, whereas in amputation all function must cease. Young stated that no work has been done to show atrophy above the anterior horn cell, but he expressed the feeling that cells not receiving stimuli from above may atrophy.[33] Tower, however, in her denervated cord preparation, found no transsynaptic deterioration. Lesions of the retina may cause the corresponding cells of the lateral geniculate body to disappear. This may be true elsewhere. A possible reason for the fact that every isolated nerve cell does not disappear may lie in the fact that increased sensitivity to acteylcholine occurs, so that cells are in constant state of incoordinated activity.[33] However, the work of Gutmann, Sanders and Young[34] offers a considerable evidence that disuse plays a major role in the atrophy of the axon under certain conditions (fig. 2). For each function there are fibers of appropriate size. They may vary from the large motor fibers, of 20 microns or more, down to the small sensory and postganglionic fibers. Evidence shows that function, rather than heredity, determines the size. The motor nerves carry many large and some small fibers, whereas the sensory nerves consist mostly of medium-sized and small fibers. If the main mixed nerve is cut and resutured, regeneration is haphazard, since there is no special attractive force directing fibers into the old channels, and yet the motor branches end up with large and the sensory with small fibers. If the mixed nerve is cut and not resewn, all proximal fibers become small. If the mixed nerve is only crushed and the motor and cutaneous branches are cut, regrowth through the crushed area into the branches will occur. The fibers in both sensory and motor nerves remain small. If the branches are then sewn and the fibers permitted to reach the muscles, the fibers which join the muscle grow large and the small unused fibers disappear — i. e., there is hypertrophy and atrophy. The influence is not the size of the tube but, rather, the peripheral organ to which it connects. Greenman showed that the reverse is true also. Fibers which lose peripheral connections undergo considerable at-

32. Hill, A. V.: Proc. Roy. Soc. London, S. B, 126:136, 1938.
33. Young, J. Z.: Lancet, 2:111, 1946.
34. (*a*) Gutmann, E., and Sanders, F. K.: J. Physiol. 101:489, 1943. (*b*) Sanders, F. K. and Young, J. Z.: Nature, London, 155:237, 1948. (*c*) J. Physiol. 103:119, 1944. (*d*) Gutmann, and Young.34a Young.33

rophy.[35] Gutmann and Sanders showed that after cut and suture the central fibers decrease for about one hundred days and increase to normal after three hundred,[36a] and Saunders and Young found that if no suture took place the secondary increase did not take place, the fibers getting smaller and bizarre in shape, with very thin axons and very thick myelin.[36]

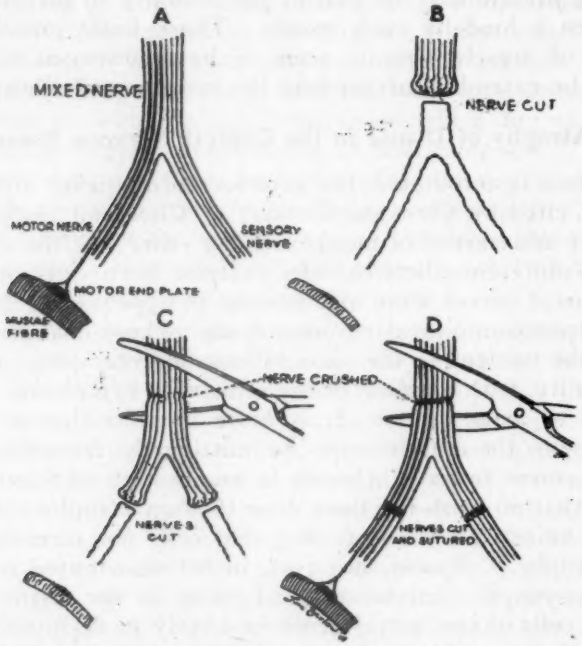


Fig. 2. — Atrophy of disuse in the motor axon. (*A*) The average size of motor fibers is larger than the average size of sensory fibers. (*B*) Motor fibers decrease in size when removed from function. (*C*) The motor fibers sheaths are apparently not the factor in fiber size. (*D*) Motor fibers increase in size on functional contact with effector organ (i. e., skeletal muscle). (Adapted from Sanders, Gutmann and Young.)

Here, again, as in muscle, is strong evidence that the stimulus for the prevention of atrophy is maintenance of specific function. If a nerve fiber can conduct impulses, it will take the size commensurate with the work it is doing — e. g., large motor fibers to conduct impulses rapidly so that muscle can contract.

Atrophy of Disuse in Bone

Howard[37] and Deitrick, Whedon and Shorr[38] have shown that in normal healthy persons put to bed in plaster fixation, calcium output increases for about five to six weeks and then maintains a consistently high level, presumably until function again takes place. With this there is an associated nitrogen loss, indicating that both calcium and protein are being lost more rapidly than in normal conditions. There is no disturbance in the deposition of calcium into the bony matrix, but the deficiency is in the laying down of the new protein bony matrix itself.[39] The wear and tear on the mature osteoid, in the meantime, continues. This leads to true disuse atrophy. The criterion

35. Greenman, M. J.: J. Comp. Neurol. 23:479, 1913.
36. Sanders, F. K., and Young, J. Z.: J. Exper. Biol. 22:203, 1946.
37. Howard, J. E.: J. A. M. A. 129:152, 1946.
38. Deitrick, J. E.; Whedon, G. D., and Shorr, E.: Am. J. Med. 4:3, 1948.
39. Albright, F.; Burnett, C. H.; Parson, W.; Reifenstein, E. C., and Roos, A.: Medicine 25: 343, 1946.

of such osteoporosis is that the blood serum calcium, phosphorus and phosphotase levels are normal.

In motor paralysis, bony density is lost.[40] Atrophy in a child regardless of the cause, produces decrease in diameter and density, whereas in an adult there is only a decrease in density.[41]

Howell's experiments on growing puppies showed that length of bone and basic features in bony configuration are determined by intrinsic factors, whereas extrinsic factors control development in bone diameter.[42] Tower also found this to be true.[3] Howell's experiments were done presumably on denervated bone, whereas Tower's were done on disused but innervated bone. This agreement, she felt, eliminated the possibility of direct neurotrophic action in growing bone, indicating that such action was due to the indirect agency of nervously initiated activity in muscle.

Abramson,[43] in a study of series of cases of peripheral paralysis due to spinal cord and cauda equina lesions, found that a large percentage of

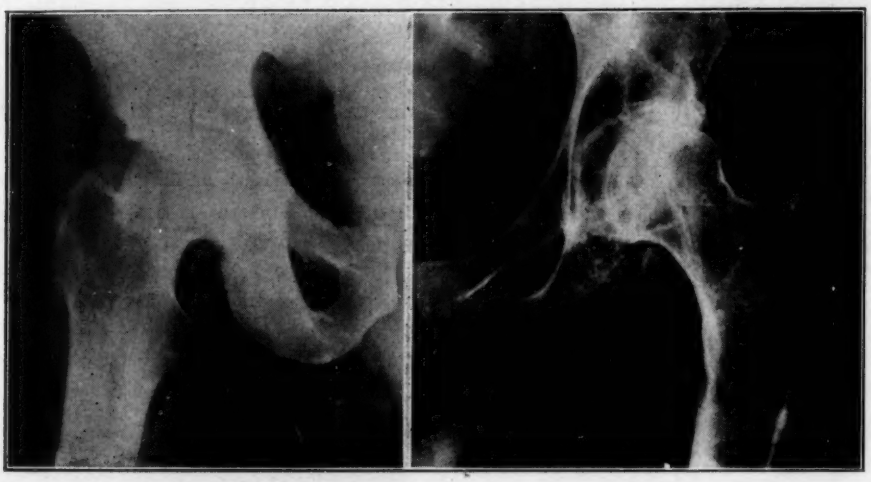


Fig. 3. — Atrophy of disuse in bone. The osteoporosis on the right occurred in a paraplegic patient who had not walked for three years. This type of osteoporosis occurs in both upper and lower motor neuron lesions. The patient whose roentgenogram is on the left, showing no evidence of osteoporosis, had walked for three years. Date of occurrence and level of lesion are the same in the two cases.

patients showed bone atrophy of a greater or less extent (fig. 3). The blood chemistry values were normal. In about half of these cases the paralysis was flaccid and in the rest spastic. The spastic patients in whom constant powerful muscular activity occurred showed atrophy to the same extent as the ones with flaccid paralysis. This would make an indirect neurotrophic action through muscular activity improbable. Stress and strain of muscle action and weight bearing may be considered, from Howell's point of view, extrinsic factors in the growth and development of bone, but in Tower's study muscle action was an indirect neurotrophic agent for the same processes. However, Abramson[43] showed that in peripheral paralysis in the lower extremities weight bearing was the stimulus for the laying down of new bony matrix. When this occurred, calcium was laid down to a greater extent and there was no atrophy.

40. DeLorimier, A. A.: The Arthropathies: A Handbook of Roentgen Diagnosis, Chicago: Year Book Publishers, Inc., 1943, pp. 130-132.
41. Goisman, J., and Compere, E. L.: J. Bone & Joint Surg.: 20:587, 1938.
42. Howell, J. A.: Anat. Rec. 13:233, 1917.
43. Abramson, A. S.: J. Bone & Joint Surg., to be published.

Thus, again, it can be shown that in bone, as in muscle, the neurotrophic influence is negligible. The important stimulus for the maintenance of bony density is primary function, which in the case of the lower extremities is weight bearing. Constant and prolonged weight bearing may lead to atrophy.[44] Intermittent weight bearing, as in ambulation, is the optimum stimulus.

Summary

1. In muscle, the optimal stimulus for the prevention of atrophy is the production of tension by contraction of the muscle itself. Contraction through a full range and against a load is best. Denervation has its influence only in making the process of disuse more nearly complete.

2. In the lower motor neuron, the optimal stimulus in preventing atrophy is the ability of the neuron and its axon to conduct impulses to a functioning effector organ.

3. In atrophy of bone, full function, again, consisting of intermittent weight bearing, is the optimal stimulus for the prevention of atrophy. Denervation plays only a little role.

Conclusion

Disuse atrophy is the decrease in sizes of tissues, due to the inability of these tissues to develop full function.

44. Weinmann, J. P., and Sicher, S.: Bone and Bones: Fundamentals of Bone Biology, St. Louis, C. V. Mosby Company, 1947.

I wish to express my sincere thanks to the Medical Illustration Department of the Bronx Veterans Administration Hospital for the preparation of the plates, to the Medical Library of the same hospital for its assistance in the preparation of the bibliography and to Mrs. Judith Levy for her aid in the preparation of the manuscript.

NEWER CONCEPTS OF ELECTRODIAGNOSIS IN PERIPHERAL NERVE INJURIES *

ALEX J. ARIEFF, M.D.

CHICAGO

Since Erb's original contribution to the response of muscle nerve complex to electrical stimuli, little has been added and much has been misinterpreted. For the most part, all that Erb described has stood the test of time. However, these tests, called "R of D," or reaction of degeneration, have their greatest use in foretelling a degenerated nerve or a denervated muscle. As for regeneration or prognostic signs, little has been contributed.

In a recent project on peripheral nerves many useful data have been obtained experimentally and been proved clinically. Electronic apparatus (Golseth and Fizzell[1]) which has been developed has been found of value in diagnosing degenerating, denervated and regenerating nerve-muscle complex.

The methods to be described deal with (I) faradic current, (II) galvanic (direct current) current rheobase (threshold twitch to galvanic current), (III) progressive current and ratio, (IV) galvanic tetanus and ratio, (V) strength duration threshold curves (discontinuities and height), (VI) chronaxie, (VII) repetitive direct current stimuli, and (VIII) polar ratio, (IX) electromyography.

All these methods utilize percutaneous stimuli, electrodes being applied in the usual fashion.

The apparatus used in obtaining all the data, exclusive of the faradic current and electromyography, was the Golseth-Fizzell Constant Current Square Wave Stimulator. An oscillogram of the wave form is shown in chart 1.

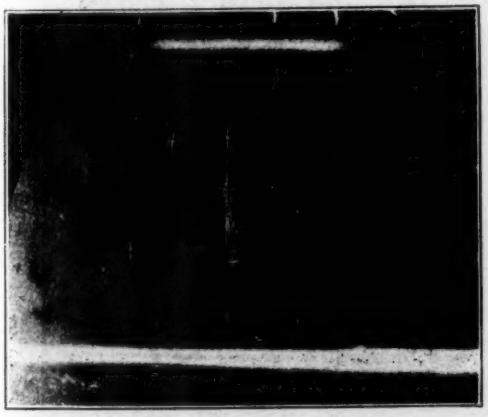


Chart 1. — Oscillogram of a constant current square wave impulse.

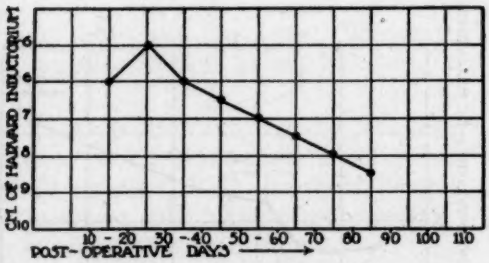


Chart 2. — The average faradic current as measured on the inductorium required to produce a minimal response of the gastrocenmius or tibialis anticus muscle (bipolar method) at varying postoperative days after primary suture of the sciatic nerve in the cat.

I. Faradic Current.[2] — Faradic current from an inductorium has stood the test of time in its ability to foretell a denervated muscle and a degenerating nerve. On the ordinary Harvard Inductorium, normal muscle responds

* From the Department of Nervous and Mental Diseases, Northwestern University.
* Read at the Midwestern Section, American Congress of Physical Medicine, Veterans Administration Hospital, Hines, Ill., Feb. 27, 1948.

1. Golseth, J. G., and Fizzell, J. A.: A Constant Current Impulse Stimulator, Arch. Phys. Med. 28:154 (March) 1947.

2. Pollock, L. J.; Golseth, J. G.; Arieff, A. J.; Sherman, I. C.; Schiller, M., and Tigay, E. L.: Reaction of Degeneration in Electrodiagnosis of Experimental Peripheral Nerve Lesions, War Med. 7:276 (May) 1945.

to 10 to 11 cm. of coupling. In ten to fourteen days after a nerve is severely injured, the nerve and muscle supplied fail to respond to faradic current in the strength ordinarily used, which is limited by the person's pain threshold. In cats, after experimental section of the sciatic nerve, the gastrocnemius

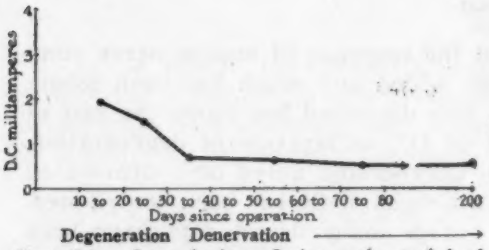


Chart 3. — Low rheobase during entire period of denervation up to two hundred days after section of the sciatic nerve.

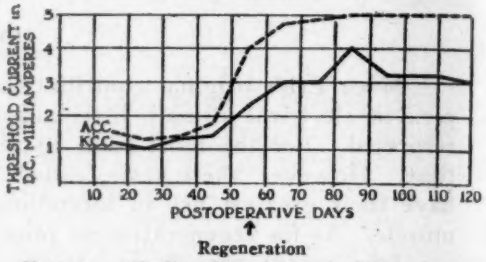


Chart 4. — Median direct current milliamperage required to produce a minimal anodal and cathodal closing contraction (Unipolar method) at varying postoperative days after primary suture of the sciatic nerve (52 animals).

muscle will respond to faradic current throughout denervation (chart 2), although the threshold becomes so great (up to 4 and 5 cm. of coupling) that the animal has obvious pain. When the threshold is low enough during regeneration to be of prognostic value, voluntary motion is usually present, making the faradic electrical test of superfluous value.

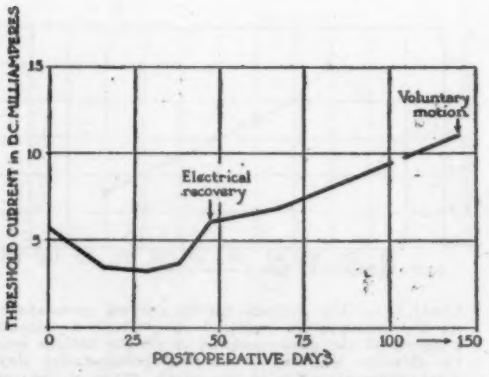


Chart 5. — Threshold current in the tibialis anticus muscle plotted against time following suture of the peroneal nerve.

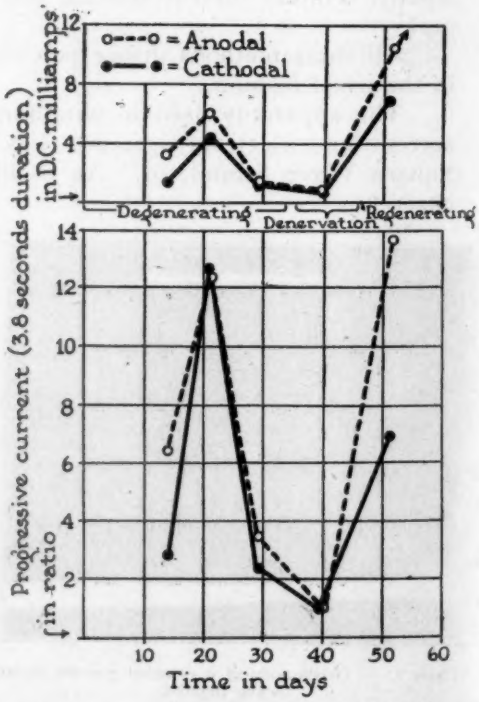


Chart 6. — Evolution of changes in threshold progressive current and progressive current ratio.

II. Rheobase. — Rheobase is defined as the threshold direct or galvanic, current lasting "infinite time" producing a twitch. The time of current flow ordinarily used is one-half second. The normal muscular response is a rapid twitch on the make of the circuit.

Erb's original description refers to an early rise in rheobase during degeneration and then a fall. The denervated muscle becomes hyperirritable

to a galvanic current of long duration and responds with a slow vermicular contraction. The latter response Erb thought most constant and characteristic of denervated muscle. If regeneration does not occur, this low threshold remains as long as muscle is present (chart 3) in this animal two hundred days after denervation. The early period of degeneration may last up to forty days until electrical denervation.

Contrary to many textbooks, an increase in rheobase is of prognostic value as a sign of regeneration. This has been borne out experimentally and clinically (chart 4). A sudden rise in rheobase indicates regeneration and may precede other signs of recovery by a long period.[3] Chart 4 shows a rise in rheobase forecasting regeneration of a sciatic nerve in the cat. Chart 5 shows a rise in rheobase or electrical recovery approximately one hundred days before voluntary motion occurred in the tibialis anticus muscle after suture of the severed peroneal nerve in man. At times the rheobase may be so high as to make a contraction unobtainable and yet prognosis may be good. However, one must exclude complicating factors such as vascular lesions and fibrosis.

III. Progressive Current.[3] — While normally the threshold for slowly rising or progressive currents is much greater than the rheobase, during degeneration the threshold early rises and then falls until at denervation both rheobase and threshold progressive current become equal, making the ratio close to unity (chart 6).

When regeneration is occurring, the first sign is a definite sudden rise in the progressive current threshold and its ratio. The progressive current ratio is determined by dividing the threshold progressive current by galvanic rheobase.

The determination of these values was made with a mechanical generator and although this data was of definite value, the observations were difficult to obtain and another method was sought for. This we found in galvanic tetanus which correlated with thresholds for progressive currents.

IV.—Galvanic Tetanus Threshold and Ratio.[4] — Although tetanus is usually obtained with a faradic or alternating current, it has been shown that using galvanic, or direct, current a sustained tetanic contraction occurs when the galvanic threshold increases three to five times the rheobase. The ratio between the rheobase and galvanic tetanus threshold is called galvanic tetanus ratio.

Rheobase is obtained with currents of infinite duration, usually 500 milliseconds on the Constant Current Stimulator. For tetanus threshold the current is allowed to flow for one and one-half seconds. The threshold for galvanic tetanus has been taken to be that point at which the muscle remains in tetanus for the one and one-half seconds that the current flows.

Early in degeneration the galvanic tetanus threshold and ratio increases and then decreases so that as denervation approaches the threshold for rheobase and tetanus are practically at unity (chart 7). A galvanic tetanus ratio of 1 is an electrical and absolute sign of denervation. The earliest sign of regeneration is an increase of galvanic tetanus threshold and ratio (chart 7). At times the threshold may be so great as to make data unobtainable with the available current.

3. Pollock, L. G.; Golseth, J. G.; Arieff, A. J.; Sherman, L. C.; Schiller, M., and Tigay, E. L.: Electrodiagnosis by Means of Progressive Currents of Long Duration, Arch. Neurol. & Psychiat. 51:147 (Feb.) 1944. Pollock, L. J.; Golseth, J. G.; Arieff, A. J., and Mayfield, F.: Electrodiagnosis by Means of Progressive Currents of Long Duration, Studies on Peripheral Nerve Injuries in Man, Surg., Gynec. & Obst. 81:192 (Aug.) 1945.

4. Pollock, L. J.; Arieff, A. J., and Golseth, J. G.: Galvanic Tetanus and Galvanic Tetanus Ratio in Electrodiagnosis of Peripheral Nerve Lesions, Surg., Gynec. & Obst. 81:660 (Dec.) 1945.

Of all the methods used by my colleagues and me, the most sensitive sign of denervation and neurotization we found by use of galvanic tetanus ratio. For practical purposes, galvanic tetanus

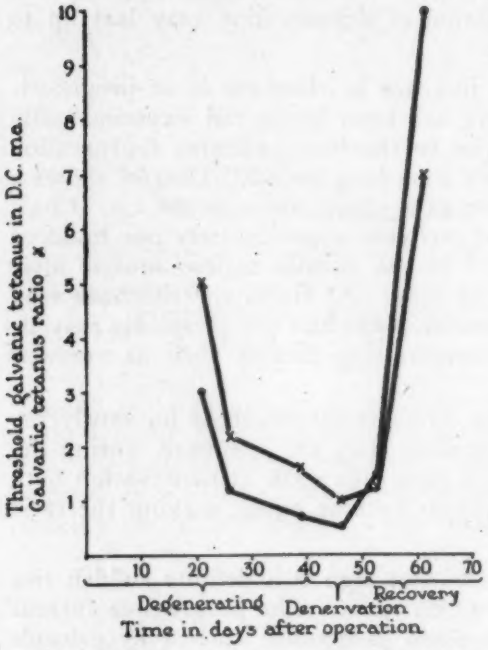


Chart 7. — Evolution of changes in threshold galvanic tetanus current and galvanic tetanus ratio.

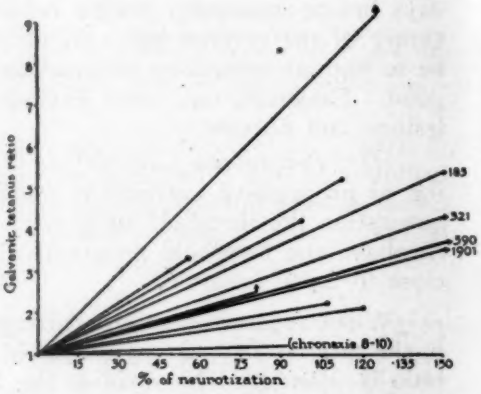
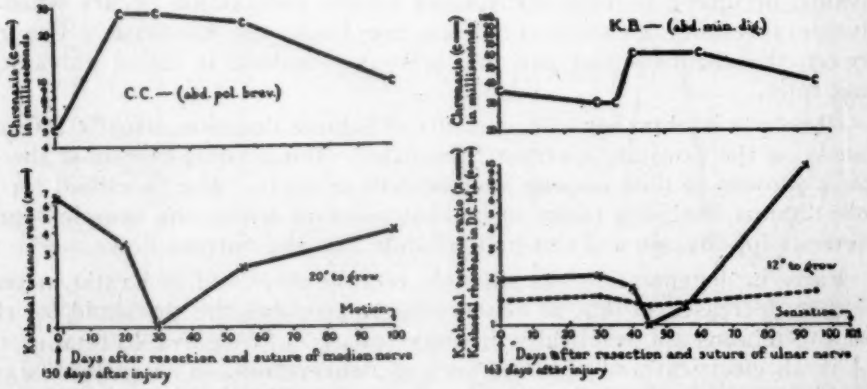


Chart 8. — Evidence of regeneration by galvanic tetanus ratio at various sutured nerves.

threshold and ratio is more accurate, is much easier to determine than progressive current and has replaced it in our electrodiagnostic examinations.

Chart 8 shows increase in galvanic tetanus ratio at varying times after suture of various nerves in man. Time is denoted in per cent of neurotiza-


C.C. — (abd. pol. brev.)
20° to grow
Motion
Days after resection and suture of median nerve
150 days after injury
K.B. — (abd. min. dig.)
12° to grow
Sensation
Days after resection and suture of ulnar nerve
163 days after injury

A B

Chart 9. — *A*, evolution of changes in galvanic tetanus ratio and chronaxie in sutured median nerves. *B*, evolution of changes in galvanic tetanus ratio and chronaxie in sutured ulnar nerves.

tion, 100 per cent being ideal time for regeneration of a nerve growing at the ideal rate of 5 mm. a day. Chart 9 shows curves for 2 patients with a median and ulnar nerve resection and suture showing evolution of changes of the cathodal tetanus ratio and chronaxie. In both patients the rise in

tetanus ratio preceded voluntary motion by many weeks. Chronaxie in these 2 cases was a late electrical sign of recovery.

V. Strength Duration Threshold Curves.[5] — By determining the thresholds for direct current stimuli of various durations, one obtains a strength duration curve. The duration of stimuli on the Golseth-Fizzell Stimulator varies from rheobase (500 milliseconds) to 1 millisecond. Muscles responding to currents shorter than 1 millisecond are considered normal, with a normal chronaxie.

Normally, the strength duration curve is continuous (chart 10). During degeneration, the curve becomes discontinuous — i. e., kinks appear in the curve (chart 10). When denervation occurs, the curve is again continuous,

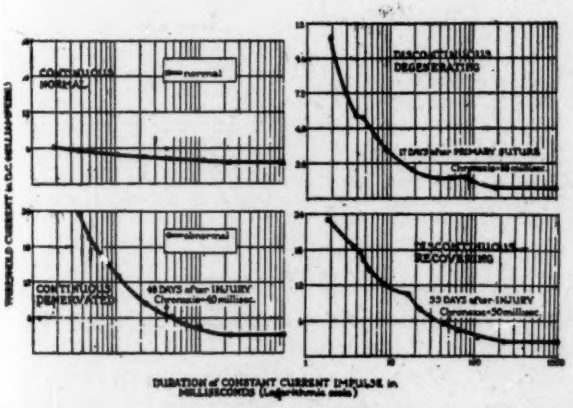


Chart 10. — Evolution of changes of strength duration curves.

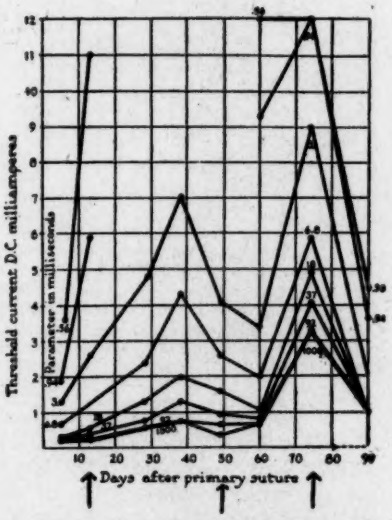


Chart 11. — Evolution of changes in height of strength duration curves.

and when regeneration occurs the curve again becomes kinked or discontinuous.

The height of the strength duration curve has been used for diagnosis. Contrary to some workers, that a decrease in height of strength duration is of value,[5b] we have found it of little importance from the fact that while earlier signs of regeneration are evident the height of the curve may be at its maximum and it does not come down until long after other clinical signs are evident. Chart 11 shows changes in the height of the strength duration curves. It can be seen that, where as motion in this particular animal returned in about sixty days, the threshold for all durations of stimuli, except for 0.56 millisecond, increased. The thresholds began to decrease about six weeks after voluntary motion had returned.

VI. Chronaxie.[6] — Chronaxie is the time in milliseconds at which twice the rheobase current is effective and is really a point on the strength duration curve. The normal value of chronaxie is less than 1 millisecond.

5. (*a*) Pollock, L. J.; Golseth, J. G., and Arieff, A. J.: Use of Discontinuity of Strength Duration Curves in Muscle in Diagnosis of Peripheral Nerve Lesions, Surg., Gynec. & Obst. 79:133 (Aug.) 1944; (*b*) Use of the Height of the Whole Strength-Duration Curve of Muscle at a Diagnostic Procedure in Experimentally Produced Lesions of the Sciatic Nerve in the Cat, Quart. Bull., Northwestern Univ. M. School 19:169, 1945.

6. Pollock, L. J.; Golseth, J. G., and Arieff, A. J.: Changes in Chronaxie During Degeneration and Regeneration of Experimentally Produced Lesions of the Sciatic Nerve of the Cat, Surg., Gynec. & Obst. 81:451 (Oct.) 1945.

Early in degeneration there is a lengthening to, and usually over, 20 milliseconds (chart 12); it may then decrease before denervation. It then lengthens during denervation and remains its longest then. During regeneration it usually shortens, but it may be a late sign compared to galvanic tetanus ratio. In the cat, when a delayed recovery occurred, galvanic tetanus ratio was a much better and earlier sign than decrease in chronaxie which

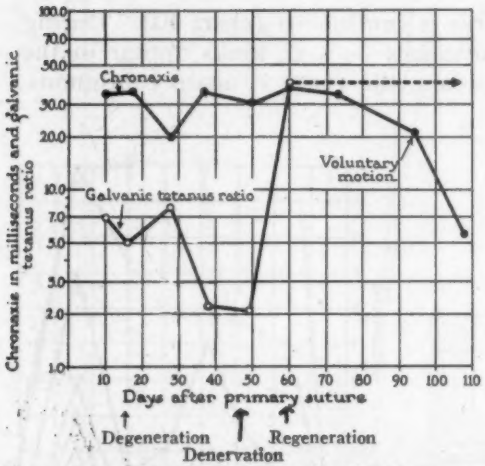


Chart 12. — Evolution of changes in galvanic tetanus ratio and chronaxie in the gastrocnemius muscle following section and suture of the sciatic nerve in the cat.

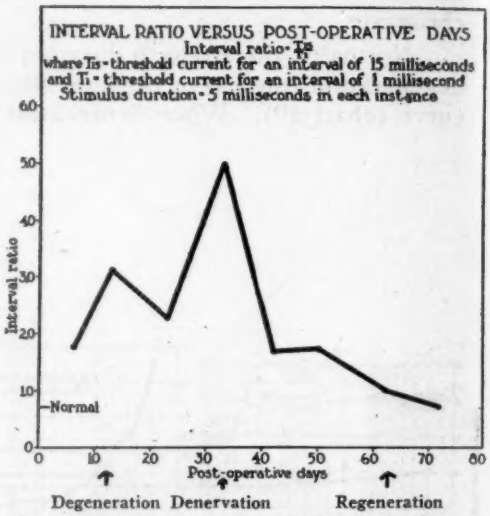

INTERVAL RATIO VERSUS POST-OPERATIVE DAYS
Interval ratio
where Ts = threshold current for an interval of 15 milliseconds
and Ti = threshold current for an interval of 1 millisecond
Stimulus duration = 5 milliseconds in each instance
Interval ratio
Normal
Post-operative days
Degeneration
Denervation
Regeneration

Chart 13. — Evolution of internal ratio in the gastrocnemius muscle of a cat after section and suture of the sciatic nerve.

came after motor recovery (chart 12). Chart 9 shows similar facts in that chronaxie was a late electrical sign compared to tetanus ratio in our clinical material. A chronaxie of over 15 milliseconds is of no prognostic value. However, when chronaxie becomes less than 10 to 14 milliseconds it is a good prognostic sign of recovery; chronaxie coupled with other signs is a very helpful one.

VII. Repetitive Stimuli.[7] — With one millisecond direct current stimuli and intervals of one to five and twelve milliseconds, normally the threshold for tetanus and twitch are very close, the value for twelve millisecond intervals being slightly less than for one millisecond intervals. That is, one can say the curve for the three values is level or descending.

During degeneration the threshold increases, being greatest for 12 millisecond intervals. Thus the relative curve for the three intervals is ascending. It increases and remains high during denervation. During regeneration the threshold decreases but does not approximate normal value until late in clinical recovery (chart 13). A leveling of the values for a tetanus for the three intervals is a good prognostic regenerative sign along with other previous signs such as galvanic tetanus ratio and chronaxie. This leveling may precede a faradic response. Chart 13 shows the relationship between intervals of one and twelve milliseconds by ratio. Normally the threshold for a twelve millisecond threshold is less than for a millisecond threshold — i. e., the ratio is less than 1 (the curve is descending). During degeneration the ratio increases, and the during regeneration the ratio decreases. However, unless the ratio is 1 or less than 1 (a level or descending curve), it is of little prognostic value and this makes it a late sign.

7. Pollock, L. J.; Golseth, J. G., and Arieff, A. J.: Strength-Internal Curves and Repetitive Stimuli in Electrodiagnosis, Surg., Gynec. & Obst. 84:1077 (June) 1947.

VIII. Polar Ratio.[8] — The literature abounds with Erb's description of polar reversal — i. e., the normal cathodal closing contraction (KCC) better than the anodal closing contraction (ACC) to ACC better than KCC, as a sign of degeneration and denervation in muscle nerve complex. Although we have found that ACC may decrease, or approximate KCC or polar ratio may be reversed, this observation has been so unpredictable as to be of little value as a prognostic sign (chart 14). Chart 14 shows the rheobase ratio ACC/KCC decreasing to unity as a late sign of degeneration in a patient with facial palsy. Voluntary motion returns long before there is a change to normal — i. e., KCC better than ACC. Because of the polar unreliability, we have used cathodal stimuli in most of our determinations to the exclusion of the anodal stimuli. Polar ratios are of experimental interest but of little clinical value.

IX. Electromyography.[9] — By means of intramuscular needle electrodes, action potentials may be picked up and amplified. These voltages may be photographed on an oscilloscopic screen or made audible by an amplifier.

Normal action potentials are diphasic and range from 500 to 2,000 microvolts. They last from five to ten milliseconds at a frequency of 5 to 30 per second (chart 15). Because of the long duration of each single wave, a characteristic thumping noise is heard in the loud speaker. When the normal muscle is completely relaxed, there is no voltage produced giving a flat base line on the oscilloscope and silence in the audioamplifier.

During degeneration about eight days after nerve injury, fibrillary potentials occur. These vary from 10 to 70 microvolts and last one to two

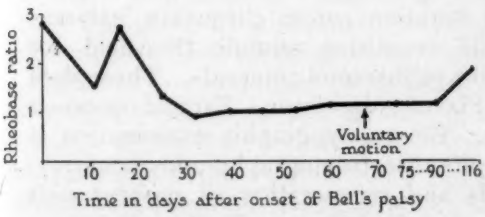


Chart 14. — Evolution of changes in rheobase ratio.

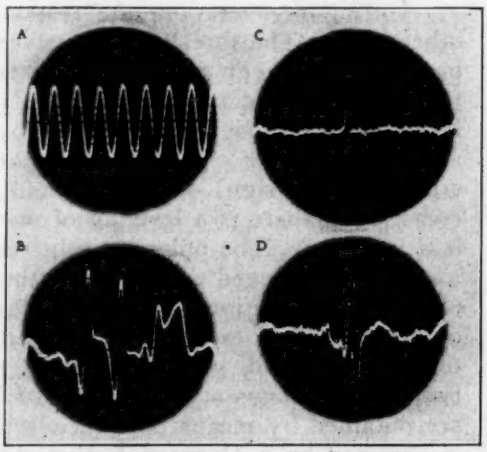


Chart 15. — Oscillograms of typical wave forms. A, sine, 200 c.p.s., 100 microvolts peak to peak. B, myogram, normal unit voltage, 1,700 microvolts peak to peak. *C*, myogram, fibrillation voltage, 30 microvolts peak to peak. *D*, myogram, nascent unit voltage, 130 microvolts peak to peak.

milliseconds (chart 15), at a frequency of 2 to 30 per second. Because they last such a brief time, they have a clicking noise. They occur, in contrast to normal, even when the denervated muscle is at rest.

During regeneration, two types of voltages may occur — fibrillation from the denervated fibers and nascent, or newborn, from recovering or neurotized muscle. The latter may be unidirectional or alternating with a com-

8. Pollock, L. J.; Golseth, J. G., and Arieff, A. J.: Military Neuropsychiatry: The Response of Muscle to Electrical Stimuli During Degeneration, Denervation and Regeneration, A. Research Nerv. & Ment. Dis., Proc. (1944) 25:236, 1946.

9. Golseth, J. G., and Fizzell, J. A.: Electromyographic Studies on Cats After Section and Suture of the Sciatic Nerve, Am. J. Physiol. 150: (Oct.) 1947.

plex wave form from 2 to 5 complete alternations (polyphasic). They vary in voltage from 40 to 600 microvolts, each wave lasting three to fifteen milliseconds at a frequency of 2 to 30 per second. Because of the spiked alternation (polyphasic), the nascent motor unit voltages give rise to a rough-sounding noise in the loudspeaker, readily differentiated from normal or fibrillary voltages. This occurs on attempted motion and is positive evidence of neurotization.

Summary

The evolution of change can be followed by the methods described.[8]

During degeneration, muscle loses its response to faradism with thresholds usually used; the galvanic rheobase early rises and falls. The threshold for progressive current and ratio early rises and falls; the threshold for galvanic current tetanus and ratio early rises and then falls; the chronaxie lengthens, and the height of the strength duration curve likewise decreases and increases. The strength duration curve becomes discontinuous. The threshold for repetitive direct current stimuli at intervals of one, five and twelve milliseconds increases, with the ratio between 1 and 12 millisecond intervals increasing from 1 to over 1. The polar ratio decreases.

During denervation, the response to faradism is absent with ordinary thresholds. The thresholds for galvanic rheobase, galvanic tetanus and ratio, progressive current and ratio is lowest. The chronaxie is longest. The strength duration curve is continuous. The threshold for repetitive direct current stimuli is highest, and the one to twelve millisecond interval ratio is highest. The polar ratio is close to unity and may be less than 1.

During regeneration, the response to faradism returns but long after other signs. The threshold for galvanic rheobase, galvanic tetanus and ratio progressive current and ratio increases. This is an early sign; galvanic tetanus ratio is the most sensitive. The chronaxie shortens, but prognostic levels are a late sign. The strength duration curve becomes discontinuous, and the height of the strength duration curve first increases and later decreases (a late sign). The threshold for repetitive direct current stimuli decreases and there is a leveling of one to twelve millisecond intervals. This is a late sign. The polar ratio increases but only as a late sign.

After prolonged evaluation of the methods used, we have finally evolved our final examination as a routine electrodiagnostic procedure. This consists of determination of rheobase, strength duration curve, chronaxie, galvanic tetanus threshold, galvanic tetanus ratio, repetitive stimuli threshold for twitch and tetanus at one, five and twelve millisecond intervals. These data are obtained by means of the Golseth-Fizzell stimulator. Faradic response is obtained by a Harvard Inductorium. Electromyographic examination is done with a custom-built electromyograph. Electromography adds confirmatory evidence of denervation potentials and regeneration of nascent unit voltages.

Conclusion

Electrodiagnosis is a definite aid in evaluating the status of nerve-muscle complex during degeneration, denervation and regeneration.

NEUROLOGIC ASPECTS OF SPINAL CORD INJURIES *

LEWIS J. POLLOCK, M.D.

CHICAGO

You are probably familiar with the treatment of the residuals of diseases of the spinal cord; with that of the flaccid atrophic paralysis of anterior poliomyelitis and the spastic paralysis as may be seen in combined degeneration of the spinal cord.

When the spinal cord or the cauda equina is severely injured the condition which results is not quite the same as one encounters in disease. Although paralysis is common to both injury and disease, rarely in disease do we encounter a complete physiologic interruption of the sympathetic nervous mechanism; in injuries of the spinal cord it is constantly interrupted. This leads to a state wherein not only is paralysis present, as in the case of anterior poliomyelitis, but, in addition, the person with a spinal cord injury is thenceforth not only paralyzed but sick in addition. The reason for this resides in the fact that there is a disturbance of many visceral functions, regulation of heat, of water metabolism, of blood pressure, heart rate, vasomotor function and many others. Whereas in anterior poliomyelitis one may have as severe a flaccid paralysis of the lower extremities as in injuries of the cauda equina, very rarely is the bladder function disturbed. On the other hand, such disturbance is constant in injuries of the spinal cord and cauda equina. This leads to complication of cystitis, pyelonephritis and renal and vesical calculi, and the care of the genitourinary tract requires constant vigilance. Many other complications appear. Bedsores or trophic ulcers frequently lead to a state of sepsis, necrosis of bone. They may appear after relatively slight trauma emphasizing the need for avoiding such trauma in exercise, ambulation, etc. As a result of trauma, myositis ossificans often develops, as well as paraosteoarthropathies leading to ankylosis. In addition to these expected unfortunate complications, injuries to the cord and cauda equina are often complicated by wounds of the viscera, lungs, liver, gastrointestinal tract and kidney, fractures and injuries to the peripheral nerves.

Not only is there a difference between injury and disease of the spinal cord, but there are differences between civil injuries, for the most part fracture dislocations resulting from diving and automobile accidents, and the injuries of war produced by missiles. First, it is rare to have survival after a gunshot injury to the cervical cord, whereas fracture dislocations frequently affect the cervical cord. Whereas gunshot wounds often injure the thoracic cord, the other fracture dislocations affect the lumbosacral spine. Fracture dislocations rarely produce the completeness of a lesion comparable to gunshot wounds. Therefore some recovery may be expected in more of them than in gunshot wounds. In the paralysis which results from injury of the spinal cord and in that which results from injury to the cauda equina, we have excellent examples of injury to the two principal components of the neuron. In the case of the spinal cord, an upper motor neuron lesion with its spastic paralysis increased deep reflexes and pathologic ones and in the case of the cauda equina, a lower motor neuron lesion characterized by flaccid paralysis, absence of reflexes and subsequent atrophy of muscle. In

* Published with permission of the Chief Medical Director, Department of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or conclusions drawn by the author.

* Read at the Midwestern Sectional Meeting of the American Congress of Physical Medicine, Veterans Administration Hospital, Hines, Ill., Feb. 26, 1948.

fact, it is the same as that which results from a lesion of a peripheral nerve which is not strange since the cauda equina consists of the anterior roots making up the motor component of a peripheral nerve.

When the spinal cord is severely injured, there is a loss of all function below the level of the lesion, a complete paralysis, a loss of all sensations and disturbance of bladder, rectal and genital functions.

When patients with complete severance of the spinal cord were examined during World War I, it appeared that there were certain differences between these lesions and only partial lesions producing, however, the same degree of paralysis and loss of sensation. It was noted that immediately after injury there was a flaccid paralysis with a loss of all reflexes; after a variable time, reflex activity returned and progressively increased so that pseudospontaneous spasms and progressively increasing flexor withdrawal occurred on suitable stimulation. These pseudospontaneous spasms were associated with excessive sweating below the level of the lesion and involuntary evacuation of the bladder, and the total reflex activity was designated as a mass reflex. Both the pseudospontaneous spasm and responses to nocuous stimuli resulted in flexor withdrawals. After a period of time hastened by infections and bedsores, the reflexes again disappeared and it was thought that the lower segment of the severed spinal cord "died." The wounded did not survive for a long period, usually dying of intercurrent infections and other complications.

In the survivors of World War II those who had injuries to the spinal cord, with the exception of those injured in the cervical cord, have survived for long periods of time. This is the result of successful treatment with antibiotics, better surgery and nursing. The picture as is now seen in patients with completely severed spinal cords is quite different from the previous description. Instead of a final period of areflexia produced by "death" of the distal segment, reflex activities have persisted. The differences between those with completely severed spinal cords and those without no longer can be observed. In both, the flexor type of spasm gradually diminished and extensor types began and increased in severity as time went on. Then in some instances they likewise diminished. Mass reflexes are rarely observed and concomitance of spasm with either automatic emptying of the bladder or excessive sweating is a rare occurrence. Crossed reflexes, rebound phenomena and stepping reflexes are seen in both complete and incomplete lesions.

Many of you are familiar with the spasticity seen in hemiplegia or in multiple sclerosis, usually characteristic of an upper motor lesion. The spasticity seen in these cases is somewhat different. If one exercises care in passively moving parts of a paralyzed extremity, in avoidance of sudden brushing or rubbing or too quickly moving such a part one is surprised at the slight resistance offered to passive movement as compared to that in hemiplegia. In hemiplegia there is a sustained resistance to even relatively slow extension of a muscle because of a heightened stretch reflex. In persons with injuries to the spinal cord, such a heightened stretch reflex cannot be demonstrated, although rapid stretch of a muscle may be a stimulus provoking a series of movements beginning with a strong contraction of the muscle so stretched and a bulging or deformation not seen in hemiplegia. Such increased reflex activity often leads to myositis ossificans, dislocations and an impediment to the healing of bedsores. The activity may often be diminished by physical therapy, careful passive movement and by hydrotherapy.

Contractures are frequently seen, especially in partial lesions of the cauda equina. In these they occur as in peripheral nerve lesions as the

result of unopposed stronger antagonists. In lesions of the cervical spinal cord they are likewise frequently seen — at times, because of a concomitant injury to the brachial plexus or anterior roots, at times because of paraylsis of only some segments innervating the muscles of the upper extremities. Especially are they frequent in the hands, appearing much as we see in leisons of the brachial plexus. More rarely do we find them in the feet, in injuries of the spinal cord and in the flexors and adductors of the thigh and flexors of the legs. These are preventable if there is an opportunity for early physical therapy. One of the troublesome symptoms in injury to the spinal cord is pain. In some it is a root pain; in very many more it is an indefinable burning pain in the extremities below the level of the lesion. When we first were commissioned with the care of these injuries, there were many instances of drug addiction and numerous complaints. This type of pain tends to begin at variable periods after injury, increase to a peak and then diminish to a degree that most are unconscious of it unless directly questioned. Indeed, recently making a survey to find any severe such pains, it was only with great difficulty that several were found in which further study was deemed indicated to find a measure for their eradication. This spontaneous submersion of sensation into the subconscious was common to most and resulted from greater preoccupation with activities and physical treatment.

In a considerable number of cases of injuries to the spinal cord an absence of reflex activity was found. This absence of activity was related to the level of the lesion in that as the levels ascended cases with reflex activity became more frequent. In such cases in the absence of both voluntary and reflex movement the muscles underwent a process of atrophy. This atrophy differed, however, from that seen in lesions of the lower motor neuron, cauda equina or peripheral nerves. The difference was found in the absence of those signs obtained by electrical examination which in the cases of lower motor neuron lesions are characterized by the term "reaction of degeneration." In these cases of spinal cord lesions, there was little polar inversion, the chronaxie was short, the galvanic tetanus ratio high and most reacted even to the faradic current. Often, however, the muscle had become fibrotic, and when a needle was inserted for what proved futile electrical examination the fibrosis could be detected by the resistance of the tissue to insertion of the needle.

Bedsores and trophic ulcers constitute one the the grave complications. In general, after the acute period following injury when some may suddenly flare to enormous proportion, they resulted from some trauma either by pressure or contusion. Their frequency may be judged from the fact that of 283 patients admitted, 193 had some form of bedsore or ulceration, 68 per cent. In most instances they were multiple, so that there were 390 ulcerations or bedsores among the 193 patients. As the result of treatment, particularly plastic surgery, their numbers diminished so that in 1946 the total number of patients with bedsores or ulcers was reduced to 116, or 40 per cent. However, despite the best of nursing, new decubiti had appeared in 18 not formerly afflicted. These occurred because of increased activity in the way of crutch walking or wheel chair activity. Injuries were sustained among other ways by striking a heel against some object, prolonged sitting in an automobile, injury in bathtubs or on exercise mats. Since the healing of these trophic skin disturbances is related to the well-being of the patient, physical therapy plays a big part in the healing of some and prevention of others.

At this time after injury the state of the bladder function is not characteristic. In 21 cases of verified complete anatomic section there were 7

instances of automatic emptying, without relation to sweating or spasm, 6 of retention and 2 of intermittent dribbling. In 7 cases of complete severance of the cauda equina, retention was present in 1, dribbling of an atonic bladder in 2, automatic bladder with almost complete emptying of the bladder in 2 and intermittent incontinence in 2. In some cases of incomplete injuries to the cauda equina some degree of voluntary micturition was possible.

In the flaccid paralysis resulting from injury to the cauda equina we are dealing with a state which from the motor standpoint is comparable to that of anterior poliomyelitis. It must be remembered, however, that in addition to the motor paralysis there is a loss of sensation and disturbed rectal and genitourinary function.

From the motor standpoint we are dealing with a flaccid paralysis, atrophied muscles and flail joints. It is among these that partial recovery of muscle power occurs spontaneously, in almost three fourths of the cases. It is, therefore, important that such cases be treated much as one would partial injury to a peripheral nerve or a potentially recoverable anterior poliomyelitis. The problem of braces, contractures, and arthrodesis is much the same, except for danger of trophic ulcers. In these cases the question of muscle atrophy differs from that in injury of the spinal cord. The atrophy is the result of denervation of the muscles, and, although the efficacy of electrical stimulation in the prevention of atrophy and facilitation of return of bulk of muscle is not conclusively proved for man, it would be neglectful not to employ it.

As is the case in anterior poliomyelitis, in other root lesions and in plexus lesions, one does not by electrical stimulation find the formula of a completely denervated muscle despite complete paralysis. Although chronaxie is lengthened, rarely do we find a tetanus ratio of 1.0 so characteristic of a completely denervated muscle. In fact, at times a contraction may result from faradic stimulation. This is due to the fact that in root lesions not all the fibers are irreversibly injured. A sufficient number of axons reach the muscle to give characteristics of a nerve muscle preparation, but they are insufficient in number to furnish the power necessary for voluntary movement.

It may be serviceable to call attention to some reflex disturbances occurring in spinal cord injuries which may in some way modify physical therapy.

The first of these relate to disturbance of temperature regulation. Some of the failure of temperature regulation is related to the absence of heat sweating below the level innervated by the proximal uninjured segment of cord. In addition, there is a diminution of area from which sensation of heat or cold may be carried from the skin to the heat regulatory mechanism in the brain.

Such disturbance of function is most frequently seen in lesions of the cervical spinal cord. Such patients are often quite ill when exposed to high temperatures. In summer they suffer intensely and frequent sponging, fans to circulate air, and an increase in intake of fluids are necessary to provide relative comfort. However, contrary to what is seen in acute experiments in animals such patients do not become poikilothermic.

Another disturbance in function is a rise in blood pressure when the bladder is distended or when an enema is given leading to headache and "black-out." A third form of disturbance is in the drop of blood pressure with "black-out" upon sudden assumption of an erect position. This is particularly liable to occur in bedfast patients and graduated exercises in change of posture tend to reduce this orthostatic hypotension considerably.

THE EFFECTS OF DIATHERMY ON THE FLOW OF BLOOD IN THE EXTREMITIES

An Experimental and Clinical Study

KHALIL G. WAKIM, M.D., Ph.D.
Section on Physiology, Mayo Clinic

JEROME W. GERSTEN, M.D.
Fellow in Physical Medicine, Mayo Foundation

JULIA F. HERRICK, Ph.D.
Division of Experimental Medicine, Mayo Foundation

EARL C. ELKINS, M.D.

and

FRANK H. KRUSEN, M.D.
Section on Physical Medicine, Mayo Clinic

With Technical Assistance of A. N. Porter

Despite the therapeutic use of short wave diathermy for more than ten years, there are relatively few studies on its effects on the circulation. Schmidt and associates[1] obtained an increase of approximately 100 per cent in the blood flow from the mesenteric vein of the dog after diathermy. Weisz and associates[2] noted arteriolar dilatation and acceleration of the circulation in the tongue of the frog after exposure to short wave diathermy. They explained the effect as being due to the hyperthermia, since a similar rise of temperature produced by other means resulted in similar changes in the circulation. Wright and Phelps[3] made plethysmographic studies on the effects of diathermy on the blood flow in the lower extremities of 3 subjects after application of diathermy to the sacrum. They obtained a decrease of blood flow in 2 subjects, and in 1 there was no change. By use of the bubble flowmeter, Kemp, Paul and Hines[4] obtained a decrease of blood flow in the lower extremities of anesthestized dogs as a result of application of diathermy. Wise[5] reported an increase of blood flow in the upper extremities of human subjects to whom diathermy was applied over the arm and plethysmograph.

With the foregoing controversial clinical and experimental reports on the effects of diathermy on the blood flow, it was deemed advisable to make a detailed study, both experimental and clinical, of the effects of diathermy on blood flow in the extremities, in order to find out more definitely whether the therapeutic application of diathermy increases or decreases the circulation in the extremities. We decided to explore the possibility that the manner of application of diathermy or the distance of the area exposed to diathermy from the part whose blood flow is being determined or both factors may account for the differences in findings reported in the literature.

---

1. Schmidt, C. R.; Beazell, J. M., and Ivy, A. C.: Effect of Heat Applied by the Elliott Treatment and Short Wave Diathermy on Blood and Lymph Flow of Intestine and Colon (an Experimental Study in the Dog), Arch. Phys. Therapy 18:677 (Nov.) 1937.
2. Weisz, Hans; Pick, Josef, and Tomberg, Victor: The Problem of a Specific Effect of Short Waves on Blood Vessels, Arch. Phys. Therapy 19:79 (Feb.) 1938.
3. Wright, G. W., and Phelps, K.: Comparison of Procedures for Increasing Blood Flow to Limbs Using Improved Optical Plethysmograph, J. Clin. Investigation 19:273 (March) 1940.
4. Kemp, C. R.; Paul, W. D., and Hines, H. M.: Studies on Blood Flow and the Efficacy of Deep Tissue Thermogenic Agents, Federation Proc. 6:141 (March) 1947.
5. Wise, C.: The Effect of Diathermy on Blood Flow; Plethysmographic Studies, Arch. Phys. Med. 29:17 (Jan.) 1948.

Methods

This investigation was divided into two parts, experimental and clinical. The experimental part of this work was done on dogs that were under pentobarbital sodium (Nembutal) anesthesia (25 mg. per kilogram of body weight administered intravenously).

In electromagnetic fields the use of apparatus containing or made of metal is out of the question because the metallic parts absorb energy under certain conditions and produce local burns. Therefore, we were obliged to resort to a method for measuring blood flow in which the apparatus involved was entirely nonmetallic. The bubble flowmeter designed by Soskin and associates[6] and modified by Dumke and Schmidt[7] was, after certain further modifications, adapted for this study on the dog. Figure 1 is a detailed diagram of the glass flowmeter which we designed for measuring the blood

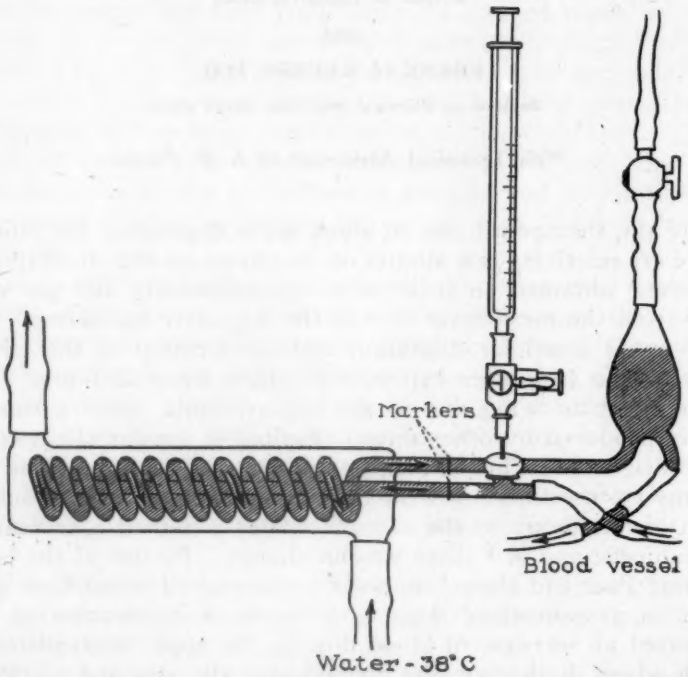


Fig. 1. — Bubble flowmeter used in the studies on blood flow in the anesthetized animal.

flow through the main vessel of the region heated by diathermy. After exposure and section of the vessel without any interference with its collateral branches and tributaries, the proximal and distal ends were connected by means of glass cannulas to the flowmeter through which the volume flow per unit of time could be measured. An air bubble about 0.2 cc. in diameter was introduced by means of a tuberculin syringe into a side opening in the flowmeter, and its course was timed between two fixed points defining the boundary of a known volume. A trap was provided in the meter to catch the injected air bubbles and prevent their entry into the circulation.

In order to reduce to a minimum the interference with blood flow that may be caused by coagulation of the blood in the flowmeter, the animal was heparinized and the meter was coated with silicon and heat-dried before

6. Soskin, S.; Priest, W. S., and Schutz, W. J.: The Influence of Epinephrin Upon the Exchange of Sugar Between Blood and Muscle, Am. J. Physiol. 108:107 (April) 1934.
7. Dumke, P. R., and Schmidt, C. F.: Quantitative Measurements of Cerebral Blood Flow in the Macacque Monkey, Am. J. Physiol. 138:421 (Feb.) 1943.

use. Silicon is an agent which protects the platelets and delays coagulation of the blood by forming an exceedingly fine and smooth lining which prevents the blood from wetting the walls of the meter.

The diathermy was applied to the extremity of the dog by the use of pads, separated from the skin by a layer of felt, one under and one above the region to be heated. Treatment was given for twenty minutes. Muscle and subcutaneous temperatures were recorded before and after application of diathermy. Blood flow readings were made before, during and after diathermy and were continued until the values returned to control level.

Subcutaneous and muscle temperatures were recorded galvanometrically by means of needle thermocouples inserted into the proper level before and after diathermy.

In the study of the effects of diathermy on the flow of blood in human extremities, the plethysmograph with a compensating spirometer recorder was used for recording blood flow. With the subject lying comfortably on the test bed, the upper and lower extremities were each placed in a plethysmograph. The part of the upper extremity sealed in the plethysmograph included the hand, the forearm and a part of the arm up to 1 inch (2.5 cm.) above the olecranon process. The leg plethysmograph covered the foot and leg up to 1 inch below the tibial tuberosity at the knee. A sphygmomanometer cuff connected to a pressure reservoir was placed around each of the extremities just proximal to the plethysmograph. This "collecting cuff" was used for occlusion of the veins during the determination of blood flow. Sudden inflation of the cuff to a pressure less than diastolic pressure, yet greater than venous pressure, trapped incoming arterial blood within the portion of the extremity distal to the collecting cuff and thereby caused engorgement and increase in volume of the part of the extremity within the plethsymograph.

After a period of adaptation (about twenty minutes) to the surroundings and the plethysmograph, the subject was instructed to lie very quietly while control blood flow readings on the extremities were established. At the end of the diathermy treatment, the blood flow in the extremities was again determined and the findings were compared with the control values on a percentage basis.

In the human subjects only temperatures of the skin over the extremities were recorded galvanometrically by use of skin thermocouples before and after diathermy treatment.

In order to study the comparative effects of various types of application of diathermy, the cable was either wrapped in the form of a coil around the limb to be treated or applied to the surface in the form of a loop or a pancake. The power output of the machine, the duration of the treatment and the manner of application of diathermy were those routinely used in physical medicine and were the same in all cases, except that occasionally when the subject experienced discomfort the output was slightly reduced. Six to eight layers of Turkish towels were routinely placed over the part of the body under the cable during the treatment with diathermy.

Results

A. Animal Studies. — After the diathermy pads were applied to the thigh of the dog, a number of control blood flow readings through the bubble flowmeter connected to the femoral artery or vein were taken before the heating was started. Then the diathermy treatment was given for a period of twenty minutes, during which blood flow readings were taken at regular intervals. After the diathermy machine had been turned off, blood flow determinations were continued for at least one-half hour.

For determining the effects of diathermy the blood flow values obtained before, during and after exposure of the region to diathermy were compared. The comparison indicated the change in flow but not necessarily the true flow, because the intact collaterals continued to carry blood from the limb to other vessels. Figure 2 represents the flow before, during and after exposure to diathermy which heated the various tissues in an extremity of an anesthetized

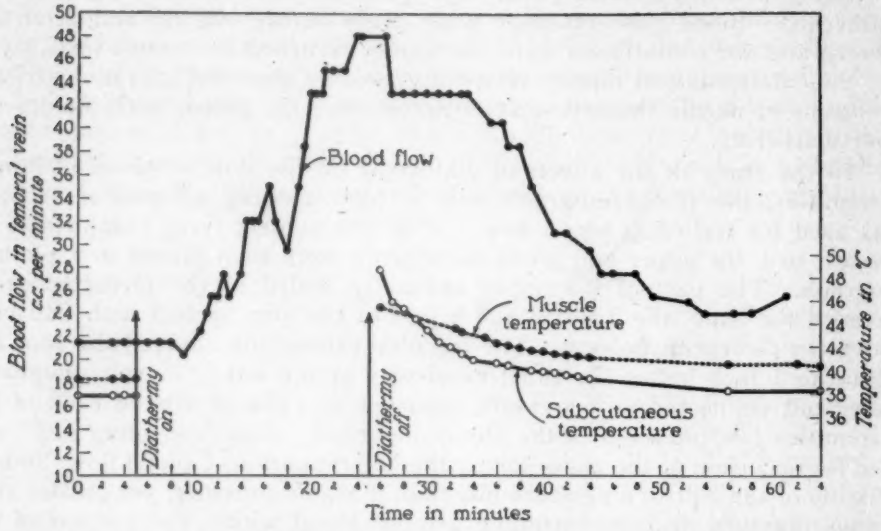


Fig. 2. — Subcutaneous and muscle temperatures before and after diathermy and blood flow in the femoral vein of an anesthetized dog before, during and after application of diathermy for twenty minutes.

Table 1. — *Femoral Arterial and Venous Blood Flow in the Anesthestized Dog During and After Local Application of Diathermy to the Extremity.*

	Average Controls Before Diathermy		During Diathermy							After Diathermy						
			Blood Flow in Femoral Vessel						Muscle Temp.	Blood Flow in Femoral Vessel						
	Muscle Temp.	Blood Flow	Maximum		Minimum		Average		Max.	Diff.	Maximum		Minimum		Average	
	°C.	Cc./Min.	Cc./Min.	% Diff.	Cc./Min.	% Diff.	Cc./Min.	% Diff.	°C.	°C.	Cc./Min.	% Diff.	Cc./Min.	% Diff.	Cc./Min.	% Diff.
Artery	38.0	47.5	74	+56	41	—14	55.5	+17	40.9	2.9	74	+56	47	—1	58	+22
	36.8	46.5	39	—16	35	—25	38	—18	41.6	4.8	62	+33	50	+8	55	+18
	36.3	43.5	37	—15	27	—38	33	—24	42.0	5.7	42.5	—2	26	—40	37	—15
	37.9	25.0	35	+40	23	—8	29	+16	40.5	2.6	53	+112	25	0	39	+56
	36.8	46.5	53	+14	41	—12	44	—5	37.7	0.9	43.5	—6	41	—12	42	—10
	37.8	34.0	94	+177	49.5	+46	70	+106	40.0	2.2	67	+97	41	+21	58.5	+72
	38.5	35.0	57	+63	34	—3	51	+46	40.4	1.9	49.5	+41	49.5	+41	49.5	+41
	37.6	33.0	74	+124	46.5	+41	63	+91	43.0	5.4	74	+124	37	+12	55.5	+68
	37.8	21.0	37	+76	21	0	30	+43	46.7	8.9	31	+48	25.5	+21	29	+38
Vein	37.0	15.0	35	+133	13.5	—10	23	+53	40.5	3.5	32	+113	19.5	+30	28	+87
	38.8	16.5	62	+276	25.5	+55	51	+209	43.9	5.1	62	+276	17	+3	40	+142
	37.8	15.0	37	+147	12	—20	27	+80	42.9	5.1	30	+100	27	+80	28	+87
	35.2	16.5	27.5	+67	12.5	—24	19.5	+18	38.8	3.6	21.5	+30	17	+3	18	+9
	39.3	16.0	40.5	+153	15.5	—3	30.5	+91	42.8	3.5	51	+219	22.5	+41	36	+125
	38.5	22.5	29.5	+31	19	—16	23	+2	41.5	3.0	32	+42	20.5	—9	26	+16
	39.3	21.5	48	+123	21.5	0	33	+53	45.5	6.2	43	+100	24	+12	35	+63
	39.9	20.0	21.5	+7.5	17	—15	19	—5	42.5	2.6	21.5	+7.5	18.5	—7.5	20	0

dog. The curves for subcutaneous and muscle temperatures are also shown.

Table 1 gives detailed data on 17 experiments, including muscle temperature before and after application of diathermy and blood flow in the femoral artery and vein before, during and after application of diathermy

to the thigh of the anesthetized dog. During the application of diathermy the significant increases over the control blood flow ranged from 16 to 209 per cent, with an average increase of 69 per cent. In 4 of the 17 experiments slight decreases of 24 per cent, 18 per cent, 5 per cent and 5 per cent from the control blood flow occurred during diathermy. After treatment with diathermy had been stopped, the significant increases of blood flow ranged from 16 to 142 per cent, with an average increase of 64 per cent. In 2 of the 17 experiments there were slight decreases of blood flow after treatment with diathermy had been stopped — namely, 15 and 10 per cent. These 2 experiments are among those that gave decreases also during application of therapy. In 1 experiment the blood flow was the same after diathermy as before it. The increase in muscle temperature at the end of the application of diathermy ranged from 0.9 to 8.9 degrees (C.), with an average increase of 4.0 degrees.

B. Studies on Human Subjects. — In order to determine the local effects of diathermy on the blood flow in the heated extremity, 36 subjects were treated

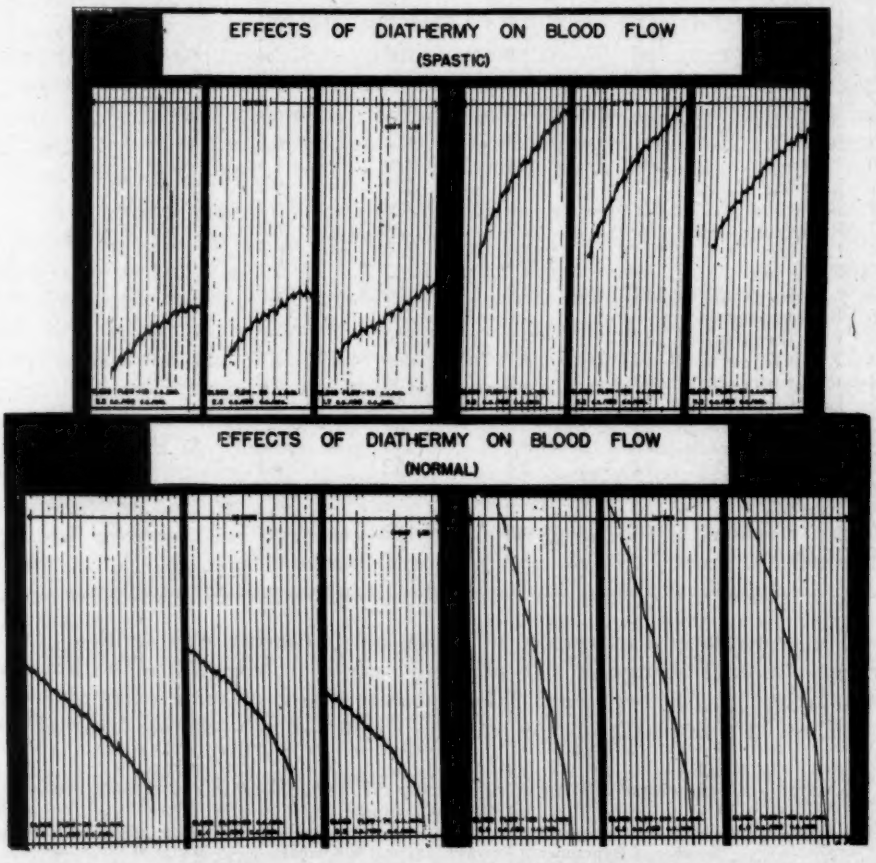


Fig. 3. — Representative blood flow curves, three before and three after heating by diathermy. The cable was wrapped in the form of a coil around the leg which was heated for thirty minutes. The upper set of curves is from the left leg of one subject, and the lower is from the right leg of another subject.

by application of the cable around the extremity (fig. 3). The average maximal change in blood flow of the heated extremity in the 36 cases was +81 per cent with a maximal increase of 341 per cent over the control. Table 2 shows the data on the individual cases in this group. Of the 36 subjects, 3 showed a slight decrease of blood flow in the heated extremity after cessation of diathermy — namely, —3 per cent, —13 per cent and —16 per cent; 3

others showed only a slight increase in the flow over the control — namely, +14, +18 and +28 per cent; while the remaining 30 subjects gave significant increases of flow, varying from +33 per cent to +341 per cent, with an average of +96 per cent over the control (table 3).

TABLE 2. — *Effects of Diathermy on Blood Flow in the Heated Extremity.*

Subject Number	Extremity Heated	Flow Before Heating Cc./Min.	Flow Before Heating Cc.%/Min.	Maximal Flow After Heating Cc./Min.	Maximal Flow After Heating Cc.%/Min.	Maximal Change Cc./Min.	Maximal Change %
1	Left leg	146	.....	219	.....	+73	+50
2	Left leg	57	.....	88	.....	+31	+54
3	Left leg	34	.....	76	.....	+42	+124
5	Left leg	42	2.1	89	4.5	+47	+112
6	Left forearm	128	10.2	194	15.5	+66	+52
7	Left forearm	170	10.6	266	16.6	+96	+57
8	Right forearm	126	7.9	167	10.4	+41	+33
10	Right leg	136	5.3	191	7.4	+55	+40
11	Right leg	151	4.3	230	6.6	+79	+52
12	Left forearm	103	6.1	138	8.1	+35	+34
13	Left forearm	148	9.3	226	14.1	+78	+53
14	Left leg	96	3.1	158	5.1	+62	+65
15	Left leg	66	2.1	106	3.4	+40	+61
16	Right leg	71	2.1	201	5.9	+130	+183
17	Left forearm	158	7.5	222	10.6	+64	+40
18	Right leg	189	7.2	262	10.0	+73	+39
19	Right leg	91	3.2	184	6.4	+93	+102
20	Left leg	104	3.4	229	7.4	+125	+120
21	Left leg	47	2.5	172	9.2	+125	+266
22	Right leg	122	3.6	228	6.7	+106	+87
23	Right leg	47	2.5	126	6.7	+79	+168
24	Left leg	103	3.0	221	6.5	+118	+115
26	Right leg	88	4.7	132	7.1	+44	+50
27	Left forearm	137	9.8	190	13.6	+53	+39
28	Right forearm	76	4.0	247	13.0	+171	+225
29	Left forearm	127	9.1	210	15.0	+83	+65
43	Right forearm	54	1.7	238	7.6	+184	+341
44	Right forearm	63	2.0	134	4.3	+71	+113
45	Left forearm	76	5.2	141	9.6	+65	+86
47	Right leg	55	.....	81	.....	+26	+47
25	Left leg	303	8.7	344	9.8	+41	+14
38	Right leg	72	2.4	92	3.1	+20	+28
46	Left forearm	148	10.0	174	15.2	+26	+18
9	Left leg	137	5.2	115	4.4	—22	—16
30	Left forearm	120	8.6	117	8.4	—3	—3
40	Right leg	86	4.3	75	3.8	—11	—13
						Average	+81

The contralateral extremity to which no diathermy was applied gave an average maximal change of +18 per cent over the control flow, with a maximal increase of 100 per cent. The untreated contralateral extremity in 10 cases showed a decrease of flow ranging from —6 to —47 per cent as compared with the control value; in 10 other cases it showed a slight increase up to 27 per cent, while in 13 cases it showed an increase ranging from +36 to +100 per cent, with an average of +54 per cent (table 3).

TABLE 3. — *Comparative Effects of Diathermy on Blood Flow in the Heated and the Unheated Extremity.*

Group Showing	Number of Experiments Heated Extremity	Number of Experiments Unheated Extremity	Average Maximal % Change Heated Extremity	Average Maximal % Change Unheated Extremity	Range of % Change Heated Extremity	Range of % Change Unheated Extremity
Flow increase greater than 30%	30	13	+96	+54	+33 to +341	+36 to +100
Flow increase up to 30%	3	10	+20	+14	+14 to +28	+ 1 to +27
Decrease of flow	3	10	—11	—23	—3 to —16	— 6 to —47
Average of all experiments			+81	+18		

In answer to the question as to how long the effects of diathermy on the circulation would last, blood flow determinations were made at certain intervals on most of the 36 subjects studied. In 27 cases blood flow studies were made on the heated extremity at the end of ten and thirty minutes after the diathermy treatment was stopped. At the end of ten minutes the blood flow in the heated extremity was +66 per cent greater than the control, and at the end of thirty minutes it was still +48 per cent greater than the control flow. In 20 subjects blood flow determinations were made on the heated extremity at the end of ten, twenty and thirty minutes after cessation of diathermy treatment. The changes in blood flow over the control in the treated extremity were +73 per cent at the end of ten minutes, +66 per cent at the end of twenty minutes and +53 per cent at the end of thirty minutes.

After diathermy had been stopped, the blood flow in the contralateral unheated extremity was determined in 24 cases at the end of ten and thirty minutes. Compared with the control values, the blood flow readings in the untreated extremity were +5 per cent at the end of ten minutes and +19 per cent at the end of thirty minutes. On 19 subjects, blood flow readings were taken on the unheated contralateral extremity at the end of ten, twenty and thirty minutes after the diathermy treatment of the other extremity had been stopped. The changes in blood flow were +5 per cent at the end of ten minutes, +12 per cent at the end of twenty minutes and +22 per cent at the end of thirty minutes.

A few experiments were performed to compare the effects on the blood flow in the same subjects when the diathermy cable was applied in the form of a coil or in the form of a loop during the heating of the extremity. In the first case, when the diathermy cable was applied in the form of a coil, the skin temperature increased in 3.7 degrees (C.) and the blood flow increased 87 per cent; but when the cable was applied in the form of a loop over the same extremity the skin temperature increased only 0.8 degrees and the blood flow showed no change. In another case the coil produced an increase of 3.2 degrees in skin temperature, and an increase of 70 per cent in the blood flow, while the loop gave an increase of 2.6 degrees in skin temperature, and only 44 per cent increase in blood flow. In the third case the coil produced an increase of 1.9 degrees in skin temperature and an increase of 52 per cent in blood flow, but the loop in the same case gave an increase of only 0.4 degree in skin temperature and a decrease of 3 per cent in blood flow.

In order to determine the effects of heating of distant regions of the body on blood flow in the extremities, the diathermy cable was applied in the form of a pancake to the lumbar region of 10 subjects. Control blood flow in the four extremities was determined before application of diathermy. At the end of the diathermy treatment the blood flow in the four extremities was again determined and compared with the controls. The average change in blood flow of the left forearm in all subjects was +40 per cent, with a maximal increase of +212 per cent as compared with the control. In only 2 cases was there a decrease of blood flow in the left forearm — namely, —11 and —19 per cent. The average change of blood flow in the right forearm of the 10 subjects was +58 per cent, with a maximal increase of +362 per cent as compared with the control (table 4). In 4 cases there was a slight decrease of blood flow in the right forearm, as compared with the control value — namely, —2 per cent, —13 per cent, —18 per cent and —27 per cent. The average change of blood flow in the left leg was +47 per cent, with a maximal increase of +213 per cent as compared with the control. Of the 10 subjects, only 2 showed a slight decrease — namely, —4 and —6 per cent;

TABLE 4. — *Effects of Application of Diathermy to the Lumbar Region on Blood Flow in the Extremities.*

Subject Number	Extremity Heated	—Flow Before Heating— Cc./Min.	Cc.%/Min.	—Maximal Flow After Heating— Cc./Min.	Cc.%/Min.	——Maximal Change—— Cc./Min.	%
48	Left forearm	132	6.9	179	9.4	+47	+36
	Right forearm	179	9.4	176	9.3	—3	—2
	Left leg	53	1.6	51	1.6	—2	—4
	Right leg	77	2.4	101	3.1	+24	+31
50	Left forearm	160	8.0	190	9.5	+30	+19
	Right forearm	155	7.7	246	10.3	+91	+59
	Left leg	47	1.9	66	2.7	+19	+40
	Right leg	58	2.4	133	5.4	+75	+129
51	Left forearm	211	10.1	170	8.9	—41	—19
	Right forearm	236	14.1	173	9.1	—63	—27
	Left leg	60	1.9	68	2.1	+8	+13
	Right leg	96	2.9	104	3.2	+8	+8
52	Left forearm	153	7.6	222	11.1	+69	+45
	Right forearm	89	4.4	198	9.9	+109	+122
	Left leg	45	1.8	45	1.8	0	0
	Right leg	44	1.8	114	4.7	+70	+159
53	Left forearm	82	5.9	129	9.2	+47	+57
	Right forearm	94	6.7	107	7.6	+13	+14
	Left leg	47	2.3	87	4.2	+40	+85
	Right leg	48	2.3	99	4.8	+51	+106
54	Left forearm	41	2.9	128	9.1	+87	+212
	Right forearm	29	2.1	134	9.6	+105	+362
	Left leg	45	1.7	141	5.4	+96	+213
	Right leg	50	1.9	122	4.7	+72	+144
55	Left forearm	200	10.0	178	8.9	—22	—11
	Right forearm	192	9.6	158	7.9	—34	—18
	Left leg	111	4.5	185	7.5	+74	+67
	Right leg	99	4.0	161	6.6	+62	+63
56	Left forearm	105	6.8	160	10.3	+55	+52
	Right forearm	86	5.5	153	9.9	+67	+78
	Left leg	61	2.3	78	3.0	+17	+28
	Right leg	60	2.3	72	2.8	+12	+20
57	Left forearm	88	4.4	92	4.6	+4	+5
	Right forearm	105	5.2	111	5.6	+6	+6
	Left leg	83	3.4	110	4.5	+27	+33
	Right leg	73	3.0	123	5.0	+50	+68
58	Left forearm	118	7.7	126	8.1	+8	+7
	Right forearm	108	7.0	94	6.1	—14	—13
	Left leg	104	4.0	98	3.8	—6	—6
	Right leg	75	2.9	86	3.3	+11	+15

TABLE 5. — *Effects of Application of Diathermy to the Lumbar Region on Blood Flow in the Extremities.*

Group Showing	Number of —Experiments— Left Forearm	Right Forearm	Left Leg	Right Leg	—Average Maximal % Change— Left Forearm	Right Forearm	Left Leg	Right Leg	——Range of % Change—— Left Forearm	Right Forearm	Left Leg	Right Leg
Flow increase greater than 30 per cent	5	4	5	7	+80	+155	+88	+100	+36 to +212	+59 to +362	+33 to +213	+31 to +159
Flow increase up to 30 per cent	3	2	3	3	+10	+10	+14	+14	+5 to +19	+6 and +14	0 to +28	+8 to +20
Decrease in flow	2	4	2	0	—15	—15	—5	None	—11 and —19	—2 to —27	—4 and —6	None
Average change for all experiments					+40	+58	+47	+74				

1 showed no change, and the rest an increase. The average change of blood flow in the right leg was +74 per cent, with a maximal increase of +159 per cent as compared with the control. None of the 10 subjects showed any decrease in blood flow in this extremity. Table 5 gives the average and range of change of blood flow in each of the four extremities of the 10 subjects.

Oral temperatures were taken on 7 of the 10 subjects before and after diathermy treatment. The average change in body temperature was +0.9 degrees (F.) and the maximal was +2.2 degrees.

Comment

The direct observations that we made during these experiments and a careful survey of the data obtained in this study convinced us that whenever efficient heating was produced by application of diathermy a substantial increase of blood flow resulted. The manner of application of the diathermy has a great influence on the degree of heating and consequently on the blood flow. For instance, in the 3 subjects in whom we compared the effects of coil application with loop application of diathermy to the region investigated, there was a substantial difference in both heating and circulating effects. In every instance application of diathermy in the form of a coil produced more heating and a greater increase of the blood flow of the treated extremity than did application in the form of a loop.

In a few cases in which the diathermy was applied to parts of the body distant from the extremities in which the blood flow was measured, the augmentation of blood flow was not as great as when the diathermy was applied directly to the extremity the circulation of which was studied.

It must be remembered that the earliest blood flow data were obtained on the average about ten minutes after the diathermy treatment had been stopped. This time was used in preparing the subjects for the plethysmographic determination of blood flow. Therefore the figures reported do not indicate the exact maximal changes of blood flow but the changes that occurred about ten minutes after the diathermy had been stopped.

Summary

The effects of various technics of application of diathermy on the blood flow in the extremities of human subjects and on anesthetized dogs were investigated. In man the blood flow in the extremities was determined by means of the air displacement plethysmograph with a compensating spirometer recorder. In the animals the bubble flowmeter was used for measuring blood flow before, during and after application of diathermy. The majority of the findings in animals as well as in man justify the conclusion that whenever efficient heating was produced by application of diathermy there was an accompanying significant increase of blood flow through the extremity. The nearer and more direct and inclusive the diathermy application was to the area the blood flow of which was measured, the more significant was the increase of blood flow.

Appendix

Factors Involved in the Heating of Tissues by Alternating Currents

Heat energy may be defined as the kinetic energy of molecules and atoms.[8] Since the kinetic energy depends on the velocity of the particle, any procedure which can increase the motion of the molecules and atoms in a system will increase the temperature of the system. Electrical heating may be divided into two general types. In one the primary effect of the applied voltage is on the free electrons in the conducting medium. In the other the primary effect is on the molecule. This classification is far

8. Kennard, E. H.: Kinetic Theory of Gases; with an Introduction to Statistical Mechanics, ed. 1, New York, McGraw-Hill Book Company, Inc., 1938, p. 5.

from complete, for the ion in electrolytic solutions is not included, but it may be a convenient starting point for a discussion of the problem of heating. The first part of the following discussion will be devoted to a consideration of the theoretical aspects of heating. The second part will consider the heating of tissues from the medical standpoint.

Theoretical Consideration. — In a conductor there are electrons which can move more or less freely through the ionic lattice of the solid. These free electrons are known as conduction electrons. When an electric field is impressed on this conductor, the free electrons are accelerated. The energy of the moving electron is soon given to the molecule, contributing kinetic energy to the thermal motion of the molecule and resulting in a rise of temperature of the conductor.[9] When the electricity is flowing through a pure resistor the amount of heat produced may be expressed by Joule's law: Heat (in gram-calories) = 0.24 × voltage × current × time (seconds). This relationship holds when it is a direct or galvanic current that is flowing.

When the current that is passing through the conductor is an alternating one, the opposition to its flow is called the impedance of the circuit. The impedance includes the resistance of the circuit and the reactance due to the presence of condensers or coils or both. In living tissues there are structures which give the effect of condensers and coils.[10] Under these conditions the foregoing formula is modified somewhat. In this category are included the eddy currents which are induced in a conductor which is exposed to an alternating magnetic field.[11] Eddy currents will be considered in greater detail in relation to the problem of induction heating.

We now come to a discussion of the effect of the alternating current on the molecule. It should be realized that the effect on the molecule occurs at the same time as that on the free electron, so that the resultant heating is due to a combination of the two factors. In this category are included dielectric hysteresis losses and magnetic hysteresis losses. Dielectric hysteresis losses exist when an alternating electric field is applied to an electric dipole molecule. This molecule is one in which the electronegative components are concentrated at one end and the electropositive components at the other end of the molecule, with a relatively large distance between the negative and positive charges. A permanent electric moment exists, which is equal to the product of this distance and the charge.[12] When the electric dipole molecule is exposed to a changing electric field it will vibrate in attempting to re-aline itself, molecular friction will take place and heat will be produced.[11] The amount of heating depends on the dielectric constant of the medium and the frequency of the applied field. The dielectric constant decreases with increasing frequency, thus tending to decrease the amount of heat produced. At high frequencies, however, the molecular rotational velocity is increased. This far outweighs the effect of the decrease in the dielectric constant, so that the generation of heat increases with an increase of frequency.[9]

Magnetic hysteresis losses exist when an alternating magnetic field is applied to a magnetic material.[11] Here again there is molecular friction, but this time it is due to re-alinement of the magnetic dipole molecule in a changing magnetic field. The amount of heat produced varies with the frequency of the changing magnetic field and the magnetic field strength. Since the magnetic permeability of body tissue is low, this factor is not an important one in the heating of tissues.

Medical Uses of Short Waves. — The heating effects of currents alternating at a frequency between 13 and 42 megacycles per second will be considered here. In condenser field heating, which is achieved by the use of pads, cuffs or air-spaced electrodes, there is a changing electric field. In human tissue, which is an electrolyte, the amount of heat produced on exposure to an alternating electric field depends on the voltage and frequency of the applied field and the specific conductivity and dielectric constant of the tissue.[13] Although human tissues are not homogenous, average values have been obtained. The average dielectric constant is close to 80, decreasing slightly with an increase of frequency.[13] The equivalent conductivity at high frequency is the conductivity of a 0.2 per cent solution of sodium chloride.[14] In a condenser field maximal heating occurs when the following relation holds: $f = \frac{2 \times c}{K}$, where f is the frequency,

9. Brown, G. H.; Hoyler, C. N., and Bierwirth, R. A.: Theory and Application of Radio-Frequency Heating, New York, D. Van Nostrand Company, Inc., 1947, p. 206.
10. Cole, K. S., and Baker, R. F.: Longitudinal Impedance of the Squid Giant Axon, J. Gen. Physiol. 24:771 (July 20) 1941.
11. Curtis, F. W.: High-Frequency Induction Heating. Ed. 1, New York, McGraw-Hill Book Company, Inc., 1944, p. 218.
12. Dole, Malcolm: Principles of Experimental and Theoretical Electrochemistry, ed. 1, New York, McGraw-Hill Book Company, Inc., 1935.
13. Osborne, S. L., and Holmquest, H. J.: Technic of Electrotherapy and Its Physical and Physiological Basis, Springfield, Illinois, Charles C. Thomas, Publisher, 1944, pp 428, 437, 456.
14. Thomson, D. L.: Internal Conductivity of Non-Irritable Muscle, J. Physiol. 65:214 (May 17) 1928.

c is the specific conductivity and K is the dielectric constant.[15] This means that at any one frequency maximal heating will occur at a definite conductivity of electrolyte. It has been shown by previous investigations that if the frequency is increased the point of maximal heating will occur at a higher conductivity. If the conductivity and frequency are kept constant, it is found that heating increases with an increase of dielectric constant.[13]

In induction heating, which is achieved by the cable technic, there is primarily a changing magnetic field. An alternating electromotive force is induced in a tissue placed within a high frequency magnetic field, and eddy currents are produced in the tissue. The coil acts as the primary of an air core transformer, and the tissue within the coil as the secondary with one turn shunted by a resistance.[13] The eddy currents alternate at too high a frequency to stimulate the neuromuscular system, but they do produce heat. The power liberated in the tissue is equal to Kf^2H^2c watts, where K is a constant, f is the frequency of the changing magnetic field, H, is the magnetic field intensity and c is the specific conductivity of the tissue.[13] The heating in the magnetic field depends on the square of the current and the conductivity of the tissue. When the current is kept constant the conductivity is the all-important factor. Since the specific conductivity of a tissue is proportional to its water content and to its electrolyte concentration,[16] and, since these are highest in vascular tissues such as muscle, which has a water content of 75 to 80 per cent, it is muscular tissue which will be heated to the greatest degree by the induction field. Fat, with a water content of 10 to 20 per cent, will absorb a relatively small amount of energy.

The foregoing factors determine the absorption of energy by a tissue. Since the energy absorbed is equal to the mass of tissue heated times the specific heat of the tissue heated times the rise of temperature, it is evident that the rise of temperature will depend not only on the energy absorbed but also on the mass heated and on its specific heat. In tissue of low specific heat (such as fat, with a specific heat of 0.4 to 0.5) the rise of temperature per unit of energy absorbed will be greater than in a tissue of higher specific heat (such as muscle, with a specific heat of 0.82). Finally, it must be remembered that the temperature reached in a tissue depends on the balance between the amount of heat absorbed and the amount of heat dissipated. We have considered only the absorption of energy. In the living body the heat is removed by the circulation, by radiation from the skin and by conduction from regions of higher temperature to those of lower temperature. The more efficient the mechanism for the removal of heat, the lower the rise of temperature will be.

15. McLennan, J. C., and Burton, A. C.: Selective Heating by Short Radio Waves and Its Application to Electrotherapy, Canad. J. Research 5:550 (Nov.) 1931.

16. Holmquest, H. J., and Marshall, J. G.: Inductothermy: Its Physical Basis and Technique of Application, Brit. J. Phys. Med. 11:70 (Aug.) 1936.

MEDICAL NEWS

American Board of Physical Medicine

The American Board of Physical Medicine which was incorporated in 1947 had certified 86 Diplomates as of March 1, 1948. Dr. Frank H. Krusen is Chairman of the Board and Dr. Robert L. Bennett is Secretary-Treasurer of the Board.

Dr. Hummon to Mercy Hospital

Dr. Irvin F. Hummon, Jr., has recently been appointed Senior Attending Physiatrist, Staff of Mercy Hospital, Chicago.

Baruch Committee Achieves Its Major Objectives

Stating that powerful physical forces which may threaten civilization are being diverted into channels which may lead to a better life, the Baruch Committee on Physical Medicine in its annual report declared that the atomic "age of physics" has released physical agents of enormous power and vast magnitude which "will in the future relieve the suffering of untold millions of sick and disabled persons and will aid in their prompt restoration to happy and productive citizenship."

Founded in 1944 by Mr. Bernard M. Baruch, elder statesman and philanthropist, in memory of his father, Dr. Simon Baruch, pioneer in physical medicine and leading American exponent of hydrotherapy, the Baruch Committee has in less than five years, according to its director, Dr. Frank H. Krusen, achieved its major objectives of: (1) Increasing the number of physicians trained to teach and use physical medicine; (2) Providing for more extensive basic and clinical research in physical medicine; and (3) Insuring the proper use of physical medicine in relation to wartime rehabilitation and peace time physical preparedness.

In issuing the report, Dr. Krusen, who is Director of Physical Medicine at the Mayo Foundation, Rochester, Minnesota, stated, "Although the full effect of the research and training of physicians will not be felt for some time, there have been immediate effects in the rehabilitation and medical care of thousands of disabled veterans and even more disabled civilians. Many disabled veterans are today living self-sufficient, independent lives in their own communities because of the increased emphasis given physical medicine and rehabilitation by the military services and the Veterans Administration, an emphasis which would not have been possible without the research, and training of physicians provided for by the Baruch Committee. Through the committee, such opportunities are gradually being brought also to the far greater number of civilian casualties of peace."

As compared with but a few limited facilities in physical medicine and medical rehabilitation, primarily in large medical centers, prior to the war, there are now, according to the report, approximately 150 communities in the nation which have or are planning civilian rehabilitation programs. Among these are the Rehabilitation Center of San Francisco, California; the Woodrow Wilson Rehabilitation Center, operated by the State of Virginia; Philadelphia, Pennsylvania, General Hospital; Bellevue Hospital, New York City; Baruch Center of Physical Medicine of the Medical College of Virginia, Richmond; and the Institute of Rehabilitation and Physical Medicine, New York University-Bellevue Medical Center, New York City.

Many of the Physical Medicine Rehabilitation Services established in each Veterans Administration Hospital as well as such services in Army and Navy Hospitals are directed by physicians whose training was sponsored by the Baruch Committee.

The effect of the committee's efforts on increasing opportunities for training physicians and other personnel in physical medicine is shown by the fact that when the committee was organized there were only five approved residencies or fellowships in physical medicine available annually in three medical centers as compared with 70 such residencies and fellowships now annually available at 34 medical centers. Compared to 30 medical schools then offering instruction in physical medicine, there are now 60, just double the original number.

Of the 33 Baruch Fellows in physical medicine who completed their training in 1947, twelve are already in teaching positions in large medical centers. Three former Fellows now hold professorships of physical medicine in medical schools, five hold assistant professorships and three hold instructorships, eight have headed departments of physical medicine in Army general hospitals, one in a Navy medical center, and four have directed departments in Veterans Administration hospitals. Since the establishment of the committee, physical medicine has become the sixteenth officially recognized medical specialty.

Of the original allocation of a million and a quarter dollars, sums totaling $900,000 were given to Columbia University, New York University, and the Medical College of Virginia to establish three centers for physical medicine and rehabilitation. The three centers, which are being developed over a 10 year period, are designed to serve as models for medical schools and hospitals both in this country and abroad.

Research and training projects are also being conducted under Committee grants at Massachusetts Institute of Technology; Harvard Univer-

(Continued on page 597)

ARCHIVES of PHYSICAL MEDICINE

OFFICIAL PUBLICATION AMERICAN CONGRESS OF PHYSICAL MEDICINE

.·. EDITORIALS .·.

WHY THE YOUNG PHYSICIAN SHOULD INVESTIGATE THE MANIFOLD OPPORTUNITIES OFFERED BY PHYSICAL MEDICINE

Physical medicine is still so new that in spite of the many favorable reports that have attended its steady advancement, there still remains a great scarcity of well-trained physicians in this field. This indicates a need for additional and constant education as to what physical medicine is and as to what the future of the specialty is.

The scarcity of physiatrists undoubtedly will continue for some time, even though there is an increase in the number of young men being trained. It will be a number of years before larger medical centers and medical schools can obtain a sufficient number of well-trained physiatrists for the purpose of further educating the medical profession in regard to the uses of physical medicine. Therefore, it becomes obvious that the interest of young physicians in this field may, at the onset, be less than their interest in other better established specialties, because they probably will not have come into contact with a sufficient number of well-organized departments and well-trained physiatrists to learn enough about the field to become interested in it. Hence, lack of knowledge may lead to erroneous impressions which may dampen the young man's incentive to become a physiatrist.

The practice of physical medicine requires a broad knowledge of several special fields. However, the fact that the physiatrist has to treat a large variety of patients with widely different conditions does not mean that he necessarily has to be a specialist in each of the branches of medicine from which his patients are referred. Actually the fact that a broad knowledge of general medicine and some branches of surgery is necessary may be stimulating to the young man when it is properly presented.

In the past, the literature concerning the clinical use of physical medicine was vague and perhaps somewhat lacking in scientific basis, as was true of the early literature in any other field of medicine. But, with the present increase in research, and the wide experience already gained in the past few years, the scientific basis of this field is now well established.

Some physicians not familiar with physical medicine may believe that diagnostic and therapeutic procedures used in physical medicine may be carried out by the physical therapist; that she is so trained that her judgment is adequate, and that there is no necessity for interpretation or prescriptions by a physiatrist. In many instances, it is assumed that the physical therapist knows sufficient physical medicine to be able to carry out the procedure, and that the special knowledge of a physiatrist is not essential. The error in such a concept is that it forces the physical therapist to become a consultant on physical medicine and to practice medicine. In addition to the very real legal aspects of such a situation, the objection immediately arises that the therapist has not had the background of training to do this, and such demands should not be made of her.

What will interest the young physician in becoming a physiatrist?

The field is new, interesting and expanding. The newness is appealing to those who have a pioneering spirit. It is a field that is challenging, in that there is much yet to be investigated. Many new physical agents, methods of treatment and diagnostic procedures remain to be explored.

Physical medicine requires the management of patients in ways different from those usually employed in other specialties. This is especially true in physical rehabilitation. It requires not only sincere interest in the patient from the psychic, sociologic and economic viewpoints, but also the willingness to followup his status for long periods. It necessitates willingness and interest in the treatment of chronic conditions. Evaluation of responses to treatment may need to be modified and the physician must endeavor many times to produce physical improvement without hope of changing the actual condition which is producing the complaint. For instance, a hemiplegic patient may not recover, but he may be taught to live happily with his condition. If the physician cannot be satisfied with this type of result, he will not be happy as a physiatrist.

One interested in physical medicine must be willing to accept certain sociologic problems presented by his patients; he must also be able to perceive many of the psychologic problems which the patient's disability presents to him. He must consider the patient's problems and difficulties as a whole. This perhaps is more true in this field of medicine than in any other.

Some form of physical medicine is indicated in a wide variety of conditions; the form to be employed may include all ages of patients and it may require much longer periods of work and contact with the patient in order to produce results than would other regimens. But many of the results are extremely satisfying.

Because of many opportunities opening in the field of physical medicine, there is now a good prospect for the young physician who wishes to obtain a responsible position early in his professional career. Medical schools and medical centers are recognizing the need for specialists in physical medicine. Since a recognized qualifying board in physical medicine has been organized, these institutions realize that they must make more interesting offers to the physician who proposes to specialize in this field than perhaps they have made in the past.

The nature of physical medicine is such that it fits well into institutional practice, such as is carried on in hospitals and clinics. Because the number of acute emergencies which require the use of physical medicine is at a minimum, it is a field which allows regular hours of practice for those who prefer this particular specialty. Because patients are referred from many other branches of medicine, physical medicine permits the physiatrist to come into close contact with many other specialties and specialists.

So far as research is concerned, the field is almost unexplored. Therefore, research problems in the field are virtually limitless. For instance, it will take many years of work to exhaust the possibilities of research in the fields of electrotherapy and bodily mechanics alone. In addition to these, physical agents exist, the application of which is as yet unexplored.

To stimulate more young men to enter the field of physical medicine, every physiatrist, in the larger centers particularly, should constantly attempt to make known to the young men the possibilities of this new field. This must be done through research, sound thinking, constant education and careful evaluation of clinical results.

Medical News
(Continued from page 594)

sity; University of Minnesota; University of Southern California; University of Iowa; Marquette University; Washington University, University of Illinois; and George Washington University. Grants have also been given to the American Association of Physics Teachers for studies on the teaching of physics as related to medical and pre-medical training.

One of the special activities outlined in the report is the work of a subcommittee which has been defining "physical fitness" and determining how the average doctor may apply the term to his patients. Previous standards of physical fitness, they reported, have been for "athletes, soldiers and other groups in supposedly good health" and have no meaning for the practicing physician unless qualified by asking "physically fit for what?" The chief goal of physical fitness, the group agreed, is "to bring the individual to that state whereby he can perform those tasks which will permit him to become an active member of society, economically independent if necessary." The subcommittee, consisting of Dr. Robert C. Darling, Columbia University; Dr. Ludwig W. Eichna, New York University; Dr. Clark W. Heath, Harvard University; and Dr. Harold G. Wolff, Cornell University, reported that motivation, "the will to do" is probably one of the most important factors in determining physical fitness.

In addition to financial support for research and training, the Baruch Committee furnishes professional consultation and advice to the universities participating in its program through its Scientific Advisory Committee consisting of Dr. Frank H. Krusen, Mayo Foundation, University of Minnesota, Chairman; Dr. John Stanley Coulter, Northwestern University; Dr. John F. Fulton, Yale University; Dr. Charles Gordon Heyd, Columbia University; Dr. Andrew C. Ivy, University of Illinois; Dr. Chauncey D. Leake, University of Texas; Dr. Frank R. Ober, Harvard University; Dr. Winfred Overholser, St. Elizabeths Hospital, Washington, D. C.; Dr. Francis O. Schmitt, Massachusetts Institute of Technology, and Dr. William S. Tillett, New York University.

Each year the committee has also sponsored special scientific exhibits at the meetings of the American Medical Association and other medical groups presenting both technical, experimental and clinical research in physical medicine and "real life" demonstrations of methods of rehabilitating arthritis, paralytics, amputees and victims of poliomyelitis and cerebral palsy.

In receiving the report from Dr. Ray Lyman Wilbur, Chancellor of Stanford, who is Chairman of the Committee's Administrative Board, Mr. Baruch stated, "This is a matter to which I have given a great deal of thought and which, I think, has already done a tremendous amount of good in alleviating the sufferings of our fellow men, particularly the veterans, and I think it will do still more. There is nothing with which I have been connected that has given me as great satisfaction."

Basil O'Connor Honored

Basil O'Connor, Chairman of the American Red Cross and President of National Foundation for Infantile Paralysis, was awarded a gold medal of the National Institute of Social Sciences. Under his guidance, the institute said, the National Foundation "has achieved a high and permanent place in the land, offering new hope for stricken youth to face courageously a brighter future."

Dr. Behneman Chief of Staff

Dr. Harold M. F. Behnemann, President of the California Society of Internal Medicine, is chief of staff of The Desert Clinic, Palm Springs, Calif.

Council Accepts Apparatus

ADC Audiometer, Model 50. — The ADC Audiometer, Model 50, is a fixed frequency instrument designed to test a person's audiroty acuity by presenting pure tones at 128, 256, 512, 1,024, 1,448, 2,048, 2,896, 4,096, 5,792, 8,192 and 11,584 cycles per second.

Liebel-Flarsheim Frequency Controlled SW-227 Short Wave Diathermy Unit. — The Liebel-Flarsheim Frequency Controlled SW-227 Short Wave Diathermy Unit generates high frequency electrical energy for the purpose of heating human living tissues in the treatment of disease.

Ille Full Body Immersion Tank Unit, Model HM-801. — The Ille Full Body Immersion Tank, also called the Ille Hydromassage Subaqua Therapy Unit for Full Body Immersion is a large metal tank big enough so that an adult lying in it can stretch out to full length, can perform maximal abduction of both thighs and can abduct the extended arms through a wide range.

Infeld Progressive Heel-Cord Stretcher Acceptable. — The Infeld Progressive Heel-Cord Stretcher is designed for use by the orthopedist to give systematic exercise to a patient with shortened tendo calcaneus. In operating the device, the foot is placed on a pedal that is free to move in such a way as to involve flexion and extension of the ankle joint only.

The Council on Physical Medicine of the American Medical Association has voted to include the following in its list of accepted devices:

Artee Curette. — The Artee Curette is a small instrument intended for use in removing foreign bodies from the surface of the eye.

The General Automatic Electrically Cooled Oxygen Tent. — The tent consists essentially of two parts, a transparent canopy suspended over the upper part of the patient's body and a cabinet, mounted on casters, through which the oxygen from a supply tank passes into the canopy.

I. E. C. Nebulizer. — This is a device made of

blown "pyrex" glass, equipped with a rubber pressure bulb and designed to convert aqueous solutions into a fine air-borne mist or nebula. The I. E. C. Nebulizer for Penicillin Aerosol has also been accepted and is a device which incorporates the inhalational nebulizer which has been accepted. — [J. A. M. A. 137:1131 (July 24) 1948.]

Pamphlets Available

"Nursing for the Poliomyelitis Patient," is the title of an 88-page, illustrated handbook which covers nursing in all stages of the disease. Preparation, publication and distribution has been financed by The National Foundation for Infantile Paralysis. Copies are available to physicians, nurses, physical therapists, occupational therapists and other professional personnel concerned with the care of the poliomyelitis patient. The handbook may be obtained by writing to the Joint Orthopedic Nursing Advisory Service, 1790 Broadway, New York 19, New York.

"Physical Therapy for Thoracic Surgery Patients, Tuberculous and Nontuberculous," is the title of a 33-page, illustrated handbook designed as a guide for the physical therapist in the management of the chest surgery patient. It may be obtained at a cost of 25 cents by writing for VA Pamphlet 10-22, the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C.

"You Can Lick TB," is the title of a 36-page, illustrated handbook for recovery of tuberculosis patients. It may be obtained by writing for VA Pamphlet 10-18, U. S. Government Printing Office, Washington 25, D. C.

Lights Out

The gadget was as flashy as a jukebox, and paid off even better. It was called the "Spectro-Chrome." A 1,000-watt bulb was propped up in the back of it, shining through red, yellow, green, blue and violet panes of glass. The instructions that came with the box reflected sunny assurance, it would "measure and restore radioactive and radio-emitive equilibrium by attuned color waves." It would also cure all diseases that man is heir to.

Patients were told to give up drugs, forget about surgery, depend on diet and the colored lights. Diabetics should eat raw and brown sugar, expose their bodies to alternate yellow and magenta lights; the yellow light was also effective for worms, magenta for heart disease, indigo for pain. Purple would decrease sex desire, scarlet increase it. Gonorrhea could be cured, in early cases, by green or turquoise, in later cases by lemon; syphilis, by two weeks of green plus four weeks of lemon. No matter what was the matter with them, said the gadget's inventor, patients should sleep with their heads pointed north, give up meat, fish, fowl, eggs, honey, coffee, tea, alcohol, tobacco, and stare at the Spectro-Chrome.

The Spectro-Chrome soon became a million-dollar business for white-goateed, bespectacled Dinshah Pestanji Framji Ghadiali. Since 1920 he has sold at least 10,000 memberships at $90 apiece in his "Spectro-Chrome Institute."

Recently the Food & Drug agents moved in on the block-long institute building in Malaga, N. J., impounded every Spectro-Chrome in the place. The FDA has also filed 25 suits to recover other known machines elsewhere, but has no idea how many others are still in use. — Time, June 7, 1948.

Rename Loyola Medical School

The Loyola University School of Medicine has been renamed the Stritch School of Medicine in honor of Cardinal Stritch. The school is undertaking to raise $12,000,000, part of which is for the new building in the West Side Medical Center, which will house both the medical and dental schools.

Fiftieth Anniversary Convention of the American Hospital Association

The American Hospital Association will hold its fiftieth anniversary convention at Atlantic City, New Jersey, September 20-23, 1948. Convention headquarters will be at the Traymore Hotel; meetings and exhibits at the Atlantic City Convention Hall. The theme of the convention will be "Hospitals — Vital to Better Living."

The American College of Physicians Announces Its Annual Session at New York City

The American College of Physicians will conduct its 30th annual session at New York, N. Y., March 28 through April 1, 1949.

Secretaries of medical societies are especially asked to note these dates and, in arranging meeting dates of their societies, to avoid conflicts with the college meeting, for obvious mutual benefits.

Homes for Paralyzed Veterans

The President has signed into law H. R. 4244, which provides certain paralyzed veterans with federal grants up to $10,000 for the purpose of purchasing or remodeling homes especially designed for wheel chair living, Veterans Administration announced.

The purpose of the law is to provide these disabled veterans, who must spend a major part of their lives in wheel chairs, with homes especially adapted to their needs.

The special features which may be incorporated in such homes include ramps, instead of steps or stairs, extra-wide halls and doorways, larger rooms, special bathroom arrangements and fixtures and, in some cases, exercising facilities.

Rehabilitation Record

On the occasion of the fifth anniversary of legislation expanding the federal-state program of vocational rehabilitation for the physically handicapped, Director Michael J. Shortley of the Of-

fice of Vocational Rehabilitation reported that more than 50,000 cases were handled successfully during the fiscal year just ended.

Heberden's Nodes

Heberden, widely known for the eponymic "Heberden's nodes," according to Stecher, dispelled the notion prevalent up to this time that these bony enlargements were due to gout. The nodes are now regarded as the most benign form of osteoarthritis, readily recognized and characteristic of this general disease.

The incidence of traumatic nodes was higher in men than in women, higher in manual workers than in physicians and higher in white manual workers than in Negroes.

Stecher did not find evidence that the production of idiopathic Heberden's nodes is influenced by climate, occupation, diet, housing, environment, habits of living, the general state of nutrition or conditions of health. Two conditions appear necessary for the development of idiopathic Heberden's nodes: a heredity constitution and intact and normally functioning nerve supply to the hand and fingers. Heberden's nodes constitute a particular form of osteoarthritis with characteristics specific for this disease. Studies of the different forms of osteoarthritis may contribute to a greater knowledge of this common affliction.

National Health Assembly

Steps toward continuing the Nation-wide cooperation stimulated by the National Health Assembly have been made public by Federal Security Administrator Oscar R. Ewing. The committee unanimously recommended organizing on a permanent voluntary basis, to provide a vehicle for carrying out the recommendations made by the National Health Assembly.

Like the Assembly itself, the continuing organization will bring together the widest possible range of professional and "consumer" groups in the health field. Its objectives will include: making plans and stimulating activities to meet national, State, and community health needs; encouraging local initiative, interest, support, and participation of the entire community in assessing their own health needs, and in developing their own programs for action; cooperating with both government and non-government organizations on national, State, and local levels; and stimulating regional, State, and local health conferences, with the broadest possible representation and support of both lay and professional groups.

The World Medical Association

Since its organization in Paris in September, 1947, the World Medical Association has made great strides. At present the national medical societies of twenty-six nations are members; applications from sixteen more nations are under consideration for admission to membership. The promotion of closer ties among the national medical organizations and the physicians of the world, the maintenance of the honor and dignity of the medical profession, mutual consideration of professional problems of the medical profession in the different countries and exchange of information on matters of interest to the medical profession, the establishment of proper relations with similar groups (such as the World Health Organization, the United Nations Educational, Scientific and Cultural Organization), improvement of health throughout the world, and the promotion of world peace are aims which merit the support of every physician. At this time through the office of the general secretary, Dr. Louis H. Bauer, surveys are in process concerning the status of the physician in different countries of the world, the standards of medical education, the qualifications and rating of specialists, the extent of recognition of cultist practice, and the advertising of medical products.

New Research Chief for VA

Dr. Alfred H. Lawton, Dean of the School of Medicine at the University of North Dakota, Grand Forks, has been appointed chief of general medical research in Veterans Administration Department of Medicine and Surgery. Dr. Lawton assumed his new duties August 1 at VA Central Office in Washington, D. C. In his new position, Dr. Lawton is supervising studies of epilepsy, psychoneuroses, hepatitis, peripheral nerve injuries and many other such diseases and wounds suffered by veterans.

Medicolegal Abstracts

Constitutionality of Law Repealing Naturopathic Practice Act. Dr. Herzog in his work on Medical Jurisprudence very clearly calls attention to the dangers flowing from the limited knowledge of the limited practitioner as follows:

While electro-therapy, mechano-therapy, hydrotherapy, suggestive therapeutics, and certain other forms of treatment for which licenses are issued to limited practitioners are valuable in many pathological conditions, the limited practitioner is likely to do a great deal of harm, not only because he is not thoroughly educated as a physician but, as he is only licensed to use a certain system of treatment, he is apt to use it in cases to which it is not adapted.

Obviously a much more accurate diagnosis may be expected from a general practitioner who has studied medicine and disease in all its phases than from a limited practitioner with only limited preparation therefor, and an accurate diagnosis of an ailment lies at the very foundation of successful methods of treatment. After all, concluded the court, why should not persons who hold themselves out to be doctors, who not only rub and massage patients but prescribe medicine for them, even though narcotics and sulfonamide drugs are prohibited, be required to have the training of a medical doctor? Evidently the legislature thought there was too much borderlining in the practice of naturopathy and determined to stamp out the evil that was not in the science

but in the practicing of it, to the definite injury of credulous sufferers.

Accordingly the Supreme Court held that the enactment of the statute in question prohibiting naturopathy in the state was a valid exercise of the police power of the legislature and that no unwarranted discrimination appears in the act. Petition for rehearing was denied and judgment of the trial court in favor of the plaintiffs was reversed. — Davis v. Beeler, Attorney General, 207 S. W. (2d) 343 (Tenn., 1948). — [J. A. M. A. 137:1153 (July 24) 1948].

Crile Residencies Available

Dr. Harrison S. Collisi, Manager, announces that there are two residencies in Physical Medicine available at Crile V. A. Hospital, Cleveland, Ohio. Crile is a 1,000 bed G. M. & S. Hospital with a completely integrated program of Physical Medicine Rehabilitation, including Physical Therapy, Occupational Therapy, Corrective Therapy, Educational Therapy and Manual Arts Therapy. The hospital has been approved for Residency Training in Physical Medicine. Dr. Harry T. Zankel is Chief of Service. Those interested may apply to the Dean's Committee, Crile V. A. Hospital, Cleveland 9, Ohio.

Promotion for Physical Therapists

The Surgeon General of the Army announces the recent promotion to the grade of major of the following seven physical therapists:

Elsie Kuraner, Army and Navy General Hospital, Hot Springs, Arkansas.

Edna Lura, Office of The Surgeon General, Washington 25, D. C.

Harriet S. Lee, Office of The Surgeon General, Washington 25, D. C.

Felie Clark, Office of The Surgeon Headquarters, Eighth Army, Japan.

Brunetta Kuehlthau, Oliver General Hospital, Augusta, Georgia.

Ethel Theilman, Medical Field Service School, Brooke Army Medical Center, Ft. Sam Houston, Texas.

Agnes P. Snyder, Office of The Surgeon General, Washington 25, D. C.

This is the first group selected for such promotion since the organization of the Women's Medical Specialist Corps.

The Arthritis and Rheumatism Foundation

Dr. W. Paul Holbrook, Tucson, Ariz., has announced the formation of a foundation to promote the study of arthritis and other rheumatic conditions. The new foundation is sponsored by the American Rheumatism Association in cooperation with the National Arthritis Research Foundation, the Detroit Fund for Crippling Diseases, and others. Seven and one-half million persons in the United States are estimated to be afflicted with arthritis or related disorders. The medical policies and activities of the new foundation will be under the direction of a medical and scientific committee now being organized. The main objectives of the new foundation include a nationwide survey of what can be done to combat arthritis. It expects to: (1) develop, with the aid of the National Research Council, a research program designed to mobilize facilities of the nation's medical schools and of the basic sciences, in the search to discover the cause and methods for the prevention and cure of rheumatic diseases; (2) establish fellowships designed to increase the number of men qualified to conduct research and to specialize in the treatment of these diseases; (3) develop key centers throughout the country devoted to research, teaching and treatment, coordinated with medical schools; (4) promote a program of medical education to increase the appreciation of the profession as a whole of what can and should be done to bring effective treatment to patients with rheumatism; (5) foster the development throughout the nation of more adequate provision for patients with rheumatism, particularly in connection with the work of general hospitals. In addition to Mr. Odlum and Dr. Holbrook, the president, the board of directors of the new foundation are:

Mr. Cyril H. Jones, Shellburne, Vt., former head of the Milton (Mass.) Academy, vice-chairman and vice-president.

Mr. Hayden N. Smith, New York, member of the firm of Winthrop, Stimson, Putnam and Roberts, secretary.

Mr. James G. Blaine, New York, president, Marine Midland Trust Company of New York, treasurer.

Mr. David G. Baird, New York, of the insurance firm of Marsh and McLennan.

Dr. Walter Bauer, Boston, director of the Robert M. Lovett Foundation for Crippling Diseases and associate professor of medicine, Harvard University.

Dr. Ralph Boots, New York, director of the Edward Daniels Falkner Arthritis Clinic at Presbyterian Hospital, and professor of clinical medicine, Columbia University College of Physicians and Surgeons.

Mr. A. B. Frey, St. Louis, attorney, and president of the National Arthritis Research Foundation.

Dr. Richard H. Freyberg, New York, associate professor of clinical medicine, Cornell University Medical College, and president of the American Rheumatism Association.

Mr. George L. Harrison, New York, chairman of the Board of New York Life Insurance Company.

Mr. H. J. McLaurin, Detroit, president of G. M. Underwriters, Inc., and general agent of Aetna Life Insurance Company, and trustee of the Detroit Fund for Crippling Diseases.

Mr. Frank Mandel, Chicago, Mandel Bros. Department Store.

Mr. Richard S. Reynolds, Richmond, Va., president of Reynolds Metal Company.

Dr. Charley J. Smythe, Plymouth, Mich., medical director, William J. Seymour Hospital, Eloise, Mich.

Dr. Robert M. Stecher, Cleveland, past president of American Rheumatism Association.

Mr. Howell Van Auken, Detroit, member of the law firm of Lucking, Van Auken, Schumann and Greiner, and trustee of The Detroit Fund for Crippling Diseases.

Mr. Charles H. Wrightsman, Houston, Texas, president, The Standard Oil Company of Kansas.

Cerebral Palsy Scholarships

Eight physicians, surgeons and therapists have been awarded scholarships for specialized training in cerebral palsy by the National Society for Crippled Children and Adults, Inc.

The scholarships were made possible under the first of six $5,000 yearly grants from Alpha Chi Omega, national women's sorority, which has adopted help to the cerebral palsied as its major national altruistic project. The scholarships will help meet the acute shortage of specialists trained in cerebral palsy, a disability of muscular control

which results from damage to control centers in the brain.

The first eight recipients are: Arline F. Bovee, Mukileto, Wash., physical therapist at the Everett, Wash., Cerebral Palsy School; Miriam Bunce, Denver, Colo., physical therapist, Colorado Society for Crippled Children and Adults, Inc.; Dr. Harriet E. Gillette, Decatur, Ga., Fellow in Physical Medicine at Emory University, Atlanta, Ga., and recently appointed Medical Director of the Crippled Children League of Georgia and of Aidmore, convalescent children's hospital operated by the League; Dr. Stanford F. Hartman, Phoenix, Ariz., orthopedic surgeon; Bette Redwine, Albuquerque, N. M., physical therapist, Veterans Administration; Dr. Louis Spekter, Hartford, Conn., chief of Division of Crippled Children, State Department of Health; Joan A. Schauble, Seattle, Wash., physical therapist and speech correctionist; and Dr. Harold Westlake, Wilmette, Ill., associate professor of audiology, Northwestern University.

The scholarships cover study at the Children's Rehabilitation Institute, Cockeysville, Md., under supervision of the Institute's director, Dr. Winthrop M. Phelps. Dr. Phelps, internationally recognized authority on cerebral palsy, is also president of the American Academy for Cerebral Palsy and chairman of the National Society's Medical Advisory Council on Cerebral Palsy.

Columbia Graduation for Therapists

A reception in honor of the graduating class of physical therapists at Columbia University, College of Physicians and Surgeons, was held Friday, August 13, 1948.

National Medical Advisory Board for VA

Dr. Robert A. Kimbrough, Jr., prominent Philadelphia physician, has been appointed a member of the Veterans Administration national advisory board on medical problems. Dr. Kimbrough succeeds Dr. Paul Titus of Pittsburgh, who resigned recently. The next quarterly meeting of the board will be held on September 13, 1948 in Washington, D. C.

Members are:

Dr. Charles W. Mayo, Mayo Clinic, Rochester, Minn., chairman; Dr. Charles F. McCuskey, Glendale, Calif.; Dr. John S. Voyles, St. Louis, Mo.; Dr. Guy W. Brugler, Cleveland, Ohio; Dr. W. S. Middleton, Madison, Wis.; Dr. Francis J. Braceland, Rochester, Minn.; Dr. Claude C. Coleman, Richmond, Va.; Dr. Francis M. McKeever, Los Angeles, Calif.; Miss Katherine J. Densford, Minneapolis, Minn.; Dr. Derrick T. Vail, Chicago, Ill.; Dr. A. R. Shands, Jr., Wilmington, Del.; Dr. Dean M. Lierle, Iowa City, Iowa; Dr. Roy Kracke, Birmingham, Ala.; Dr. A. C. Christie, Washington, D. C.; Miss Eleanor Cockerill, Pittsburgh, Penn.; Dr. J. Stewart Rodman, Philadelphia, Penn.; Dr. George F. Cahill, New York, N. Y., and Dr. William A. Hunt, Chicago, Ill.

Dr. Feuer Heads New Program

Plans have been completed by the Jewish Sanitarium and Hospital for Chronic Diseases, East Forty-ninth Street and Rutland Road, Brooklyn, for a new department of physical medicine and an extensive rehabilitation program.

Patterned after the Institute of Rehabilitation of the New York University - Bellevue Medical Center, the facilities will be housed in a $2,500,000 six-story building now under construction and expected to be ready for the patients next March.

The rehabilitation program would embrace the newest concepts of physical medicine, hydrotherapy and occupational therapy, which will endeavor to give some degree of independence or semi-independence to groups of patients, who, until now, were hopelessly disabled for life.

Conference to Correlate Rehabilitation

Representatives of three armed services and two government agencies met in the office of the Army Surgeon General on June 28 for the benefit of crippled servicemen, ex-servicemen and civilians. A conference on physical medicine and rehabilitation was held then to plan correlation of all government medical efforts in that field. Participating will be the Army, Navy, Air Forces, Veterans Administration and U. S. Public Health Service, together with civilian consultants of each. Among those participating was Dr. Frank H. Krusen, director of the Baruch Committee on both the Army and the Veterans Administration. Armed services conferees were representatives of the physical medicine units of each agency, led by Lieut. Col. B. A. Strickland, Jr., chief of the physical medicine consultants division of the Army Medical Corps.

BOOK REVIEWS

THE 1947 YEAR BOOK OF PHYSICAL MEDICINE. Edited by *Richard Kovâcs,* M.D., Professor of Physical Medicine, New York Polyclinic Medical School and Hospital; Attending Physical Therapist, Manhattan State, Harlem Valley State, Columbus and West Side Hospitals; Visiting Physical Therapist, New York City Department of Correction Hospitals; Consulting Physical Therapist, New York Infirmary for Women and Children, Mary Immaculate Hospital, Jamaica, N. Y., St. Charles Hospital, Port Jefferson, R. I., Hackensack Hospital, Hackensack, N. J., and Alexian Brothers Hospital, Elizabeth, N. J. Senior Consultant in Physical Medicine and Medical Rehabilitation, Veterans' Administration. Cloth. Pp. 432, with 152 illustrations. Price, $3.75. The Year Book Publishers, Inc., 304 So. Dearborn St., Chicago 4, Ill., 1948.

This volume is the tenth in the series which began in 1938 with the publication of the Year Book of Physical Therapy. The passage of a decade of constant progress since that first volume appeared offers a fitting occasion to congratulate Dr. Kovács, the author on his part and the part of this Year Book in the wonderful progress of Physical Medicine in this period. In 1938 the status of physical medicine in the United States was fairly well established. Under the impetus of the real recognition given this specialty for the first time during World War I, hospital departments of physical therapy had been organized in increasing numbers and a good deal of graduate and undergraduate teaching inaugurated replacing the earlier, objectionable, commercialized teaching. The American Congress of Physical Medicine served as a rallying point for physicians interested in physical medicine. The American Medical Association in 1925 created the Council of Physical Therapy now the Council on Physical Medicine. This council exerted much effort to foster education and research and to protect the profession and the public by critical evaluation of claims for apparatus. Physical therapists had their strong organization, the American Physical Therapy Association which did commendable work.

Long a leader in the field of physical medicine and currently the Secretary of the American Congress of Physical Medicine, the editor of this volume, Dr. Kovács, has both the professional training and the experience necessary to present and interpret the growing field of physical medicine. Preeminently a teacher and an author, anyone who has a library of physical medicine will at once recognize that the name of Kovács is on more books on Physical Medicine than anyone else in the world.

In this volume there is given a table showing a classification of subject matter from 1938 to 1946 as reflected by the number of pages of material in the Year Book of Physical Medicine. It will be noted that during the past five years articles on exercise, occupational therapy and physical rehabilitation have occupied more and more space undoubtedly because of the effects of World War II. Among special clinical subjects infantile paralysis has held first place with chronic arthritis and traumatic conditions next. Hypothermy leads among newer methods reported on, with only a small amount of work on ultrasound. This volume brings for the first time a report on a newer form of diathermy, microwave or radar heating.

This volume is the best of the ten. The factual material which Dr. Kovács presents has been scattered in dozens of professional journals. Its synthesis into one volume together with his experienced analysis and stimulating style makes this volume one that should be read by every physiatrist, general practitioner and physical therapist.

PHYSIOLOGY OF EXERCISE. By *Laurence E. Morehouse,* Ph.D., Associate Professor of Physical Education, The University of Southern California; Formerly Research Fellow, Harvard Fatigue Laboratory and *Augustus T. Miller,* Jr., Ph.D., Associate Professor of Physiology, University of North Carolina Medical School. Cloth. Price, $4.75. Pp. 353, illustrations 50. The C. V. Mosby Company, 3207 Washington Blvd., St. Louis 3, Missouri, 1948.

The reader will be impressed with the arduous experiments on which our present understanding of the physiology of muscular exercise rests. It is not enough to make studies of frogs' nerve muscle preparations of swimming rats and of panting dogs. Man himself must be the subject; many of the advances in exercise physiology have come from self-experimentation. The examples of Barry Wood spending Saturday evening in the Fatigue Laboratory studying blood samples collected from himself and his fellow football players during the afternoon, of Sid Robinson running to exhaustion on the treadmill with unheard of blood lactate concentrations, of Ancel Keys, cold and anoxic, undergoing arterial punctures during six days at 20,000 feet, of Harold Edwards keeping pace on dessert sands with a burro give one a picture of the stuff from which exercise physiologists are made.

Such experimenters refused to accept the opinion expressed in some quarters before the war that the day of hard work was over; that mechanization has made industrial work easy and that the soldier would be able to ride to battle. Physical ruggedness has its virtues in both management and labor circles. The physical fit soldier

has the best chance of survival and of defeating his foe. The authors believe correctly that quite apart from satisfying his scientific curiosity about uncharted fields, the exercise physiologist can take satisfaction from the fact that his research has contributed to the well-being of man at work and to the fighting effectiveness of the combat soldier.

ESSAYS ON HISTORICAL MEDICINE. By *Bernard J. Ficarra,* A.B., ScB., M.D. Professor of Research Biology in Charge of Experimental Physiology, St. Frances College, Brooklyn, N. Y.; Diplomate of the American Board of Surgery, Member of the American Association of the History of Medicine, New York Society for Medical History, New York Academy of Sciences. Cloth. Price, $5.00. Pp. 220. Froben Press, Inc., 4 St. Luke's Place, New York 14, N. Y., 1948.

This book contains eighteen essays on historical medicine. The author says that these essays do not pretend to be a complete or detailed work on the vast subject of medical history. They are a compendium of interesting historical events blended into several distinct essays. In this way a changing foreground with a stable background has been molded into historical scenes.

The author makes these essays interesting not only from their history but from his reflection. For instance his comments in his essay "Famous cripples of the past" are interesting. The pages of history are replete with names of persons whose fame rests on their soulful accomplishments, yet they were handicapped by deformity of body. Human physical afflictions resulting in bodily deformity have been the source of sorrow since man learned to recognize the wrath of disease. Little if any, thought has been given to the truism that the essential character of man is altered not by external appearance but according to the perfection of the attributes of the soul. The essays make interesting reading for any physician.

TREATMENT OF HEART DISEASE. By *William A. Brams,* M.S., M.D., Ph.D., Associate Professor of Medicine, Northwestern University Medical School and Attending Physician, Michael Reese Hospital, Chicago. Cloth. Pp. 195, with 11 illustrations. Price, $3.00. W. B. Saunders Company, 218 West Washington Square, Philadelphia 5, 1948.

The author correctly states in his preface: "Many years of clinical teaching, private practice and consultation work have convinced me that the general practitioner and medical student feel a great need for a systematic and practical guide in the treatment of heart disease." No attempt has been made to include descriptions of additional methods favorably reported by others.

Such ideas apply to physical medicine in heart disease. Some of the author's statements are: "The degree of activity permitted while in bed will depend on the progress of recovery but no error will be committed in case of doubt by adopting a conservative attitude." "The care of the patient does not end when he leaves his bed. Proper supervision is important after he becomes ambulatory." "Moderate exercise is permissable provided that it does not cause undue dyspnea, fatigue, palpitation or other signs of cardiac embarrassment." "The dangers of hot baths and steam baths, sweat cabinets and similar measures should be pointed out." This book should be read by physiatrists interested in the treatment of heart disease.

HOW LAYMEN CUT MEDICAL COSTS. Public Health Institute of Chicago. Fabrikoid. Pp. 36. The Lakeside Press, R. R. Donnelley & Sons Company, Chicago, 1948.

This is a brief monograph which tells the story of the Public Health Institute of Chicago.

CLINICAL DIAGNOSIS BY LABORATORY METHODS. A Working Manual of Clinical Pathology. By *James Campbell Todd,* Ph.B., M.D., Late Professor of Clinical Pathology, University of Colorado School of Medicine; *Arthur Hawley Sanford,* A.M., M.D., Professor of Clinical Pathology, Mayo Foundation, University of Minnesota, Senior Consultant, Division of Clinical Laboratories, The Mayo Clinic with the Collaboration of *George Giles Stilwell,* A.B., M.D., Division of Clinical Laboratories, The Mayo Clinic. Eleventh Edition, Cloth. Price, $7.50. Pp. 899 with 397 illustrations. W. B. Saunders & Co., 218 West Washington Square, Philadelphia 5, 1948.

This is the eleventh edition of an outstanding classic of laboratory books. This new edition has been completely revised since the appearance of the last one in 1943 and includes new material on blood groups, vaccines, biologic skin tests and medical mycology. The latest advancements in the other fields are also considered. New colored and black and white illustrations have been added. A book with this enviable reputation needs no recommendation. The authors have merely brought the book up to date in keeping with the new developments in clinical pathology. Its excellence has been maintained.

A SYNOPSIS OF SURGICAL ANATOMY. By *Alexander Lee McGregor,* M.Ch. (Edin.), F.R.C.S. (Eng.), Surgeon, Johannesburg General Hospital, Lecturer on Surgical Anatomy, University of Witwatersrand. With a foreword by Sir Harold J. Stiles, K.B.E., F.R.C.S. (Edin.). Sixth Edition. Cloth. Pp. 671, with 699 illustrations. Price, $6.50. Williams & Wilkins Co., Mount Royal and Guilford Aves., Baltimore 2, 1946.

This book should be helpful to students and busy practitioners; its concise method should make it useful for review purposes. The book is divided into the anatomy of the normal and the anatomy of the abnormal. The attempt has been made to present the material more from a practical viewpoint than to cover the subject of anatomy in every detail. The illustrations, although small are schematic and serve their purpose well. Six editions since 1932 attest to its popularity.

LAW AND THE PRACTICE OF NURSING. By *Nettie D. Fidler,* R.N., B.A., Assistant Professor of Nursing, School of Nursing, University of Toronto, in Collaboration with *Kenneth G. Gray,* K.C., M.D., B.Sc. (Med.) E.D. Lecturer in Medical Jurisprudence and Forensic Psychiatry, University of Toronto. Cloth. Price, $2.00. Pp. 106. Ryerson Press, 299 Queen St., W., Toronto 2, Canada, 1947.

The volume Law and the Practice of Nursing pertains to the legal status of the nurse and outlines the legal privileges, legal duties and obligations acquired by the nurse practicing in the Dominion of Canada and which do not apply to other persons in the community. A stipulation is made that when the term "law" or "the law" is used, it means a body of rules which will be enforced in the courts. In the Dominion of Canada law is derived from two sources of law, legislation and judgments of the court. It states that under the constitution the power to legislate (that is, the power to change the law is divided between the Parliament of the Dominion of Canada and the Legislatures of the nine Provinces. The Parliament has the exclusive power to legislate in respect to certain subjects (such as criminal law), whereas the Provincial Legislatures have the power to legislate in respect to other subjects (such as property and civil rights). The power to legislate in respect to the practice of nursing is assigned to the Provincial Legislatures. The Parliament has no power to legislate in this field and it is for this reason that there is such a variation in the legal status of nursing between Provinces.

A judgment of a court in the Canadian legal system forms a precedent which will be followed by other courts deciding future cases in which the facts are the same. A judgment can only be varied by a decision of a higher court or by legislation (that is, Parliament or a Legislature). It is, therefore, evident that when a court pronounces a judgment the court is the source of law. They do not make law, they only declare the law as it has always been. When a judgment is pronounced it must be followed in all future cases unless the judgment is reversed by a Superior Court or by legislation.

The authors further state that necessary as is a knowledge of the law in regard to individual situations, nurses, after all, seldom become embroiled with the law. This is certainly not true in our United States Courts.

The background and qualifications of the authors make this book authentic in every respect. An extensive bibliography enhances its value. This volume is easy to read, states the facts briefly and omits much of the legal phraseology which it is possible many of the courts, including our own, use to confuse the average plaintiff or defendant.

Of course, most of the information contained in this book, especially that pertaining to the Canadian laws, while stated clearly and while informative, could only be interesting or useful to nurses actually practicing their profession in the Dominion of Canada. However, the reader will find a wealth of useful information regarding the nursing profession as a whole. The chapter concerning "Health Insurance" will undoubtedly prove to be particularly interesting. The authors point out that the health service in the Dominion of Canada is far from adequate.

All in all, this book is well worth reading, not only by the nursing profession but by the medical profession as well. It should be included in every medical library as a reference book and should also be put into every school of nursing. A physician or a nurse need only be involved in one medical-legal action, as the defendant, regardless as to whether the case goes to court or not, to appreciate the value of authentic medical-legal information of the type contained in this volume.

DIAGNOSIS AND MANAGEMENT OF THORACIC PATIENT. *Charles P. Bailey,* Editor. American Practitioner Series. Cloth. Pp. 334. Price, $4.00. J. B. Lippincott Company, 227-231 S. 6th St., Philadelphia 5, 1946.

This work is reprinted from *Clinics* and is recommended for all interested in thoracic surgery.

AN INTRODUCTION TO PHYSICAL METHODS OF TREATMENT IN PSYCHIATRY. By *William Sargent,* M.A., M.B. (Cantab.), M.R.C.P., D.P.M., Physician, Maudsley Hospital; Acting Clinical Director, Sutton Emergency Hospital; Hon. Psychiatrist, West End Hospital for Nervous Diseases, London, England; Visiting Professor of Neuropsychiatry (1947-1948), Duke University Medical School, U. S. A.; and *Eliot Slater,* M.A., M.D. (Cantab.), F.R.C.P., D.P.M., Physician in Psychological Medicine, National Hospital, Queen Square; Physician, Maudsley Hospital, London. With a Chapter on Treatment of the Epilepsies by *Denis Hill,* M.B. (Lond.), M.R.C.P., D.P.M., Physician in Psychological Medicine, King's College Hospital; Physician in Charge, Department of Applied Electro-Physiology, Maudsley Hospital; Assistant Physician, Department of Applied Electro-Physiology, National Hospital, Queen Square, London. Second Edition. Cloth. Price, $3.50. Pp. 215. The Williams & Wilkins Company, Mount Royal and Guilford Aves., Baltimore 2, 1948.

The title of this book may be misleading to those in the field of physical medicine as physical therapy in the usual sense is not discussed. The greater part of the contents deals with insulin treatment of schizophrenia and convulsion therapy both medical and electrical.

The technic is discussed in considerable detail as well as indications and results. One chapter is devoted to treatment of epilepsy and another to the treatment of general paralysis. The use of penicillin and malaria but not of artificial, mechanically induced fever is dealt with. Other sections are devoted to subjects of chemical sedation including continuous sleep and the combined use of drugs with psychotherapy. There is also a short chapter on prefrontal leucotomy. This small book should be of interest to psychiatrists

desirous of having available practical information on the use and value of these accepted and important methods of treatment of psychiatric patients.

CORRELATIVE NEUROANATOMY. By *Joseph J. McDonald,* M.S., M.Sc.D., M.D.; *Joseph G. Chusid,* A.B., M.D., and *Jack Lange,* M.S., M.D. Fourth edition, revised. Pp. 156, with 60 illustrations. Price, $3.00. University Medical Publishers, Palo Alto, Calif., 1948.

This small manual gives in outline form the anatomy and elementary physiology of the nervous system both central and peripheral. It is illustrated by numerous diagrams including the peripheral nerves and major motor and sensory pathways of the central nervous system. All the common and some of the rare pathologic conditions are mentioned and the important signs and symptoms are correlated with the anatomical data. The essentials of neurodiagnosis are covered including description of reflexes, electrical examination, pneumography, cerebral spinal fluid findings and also electroencephalography.

This new edition is improved by considerable rearrangement of subject matter. The flexible ring binding is convenient for student use. This is recommended as an excellent text for nurses and medical students. The reviewer has also used it with satisfaction as a reference source in instruction courses for physical and occupational therapists, although therapeutic measures are not included.

A WAY TO NATURAL CHILDBIRTH. A MANUAL FOR PHYSIOTHERAPISTS AND PARENTS-TO-BE. By *Helan Heardman,* Diploma, Bedford Physical Training College. Chartered Physiotherapy (Teacher's Certificate). Fabrikoid. Pp 124. Price, $2.50. Williams & Wilkins Company, Mount Royal and Guilford Aves., Baltimore 2, Md., 1948.

According to the author's preface, there is nothing new in the exercises used, which are adaptations from those brought to that country many years ago in the system of Per Henrik Ling, and now known as Ling's System of Swedish Gymnastics and Swedish Remedial Exercises. Prof. F. J. Browne says nothing has been more remarkable in the practice of obstetrics within the last ten years than the increasing appreciation of the value of the principles enunciated by Edmund Jacobson in 1929 in his book, "Progressive Relaxation," and afterwards applied to midwifery by Grantly Dick Read in his two books on childbirth.

THE FOOT AND ANKLE: THEIR INJURIES, DISEASES, DEFORMITIES AND DISABILITIES. By *Philip Lewin,* M.D., F.A.C.S., Associate Professor of Bone and Joint Surgery and Acting Head of Department, Northwestern University Medical School; Professor of Orthopedic Surgery, Postgraduate Medical School of Cook County Hospital, Attending Orthopedic Surgeon, Cook County Hospital, Senior Attending Orthopedic Surgeon, Michael Reese Hospital, Consulting Orthopedic Surgeon, Municipal Contagious Disease Hospital, Chicago; Formerly Colonel, Medical Corps, Army of United States. Third Edition. Cloth. Price, $11.00. Pp. 847 with 389 illustrations (Line Drawings by Harold Laufman, M.D., F.A.C.S., Associate in Surgery, Northwestern University Medical School, Formerly Major, Medical Corps, Army of the United States). Lea & Febiger, Washington Square, Philadelphia 6, Penn., 1947.

The third edition of this popular book has been extensively revised. A considerable amount of new material has been added. A large number of new illustrations have been incorporated. The book contains the latest recognized facts and reflects present day concepts of etiology, diagnosis and treatment.

Compound fractures, crushing wounds and osteomyelitis have been given additional emphasis in this edition. Many pages and several illustrations discuss the military aspects in training and on the battlefield. The sections on traumatic gangrene and amputations have been amplified. Ringworm is considered not only as a primary and sole infection but also as a complication of other injuries. The conservative treatment of club foot by the Denis-Brown splint is given.

Military expediency has brought forth some new and often startling facts which are given, such as: (1) newer research in chemotherapy (penicillin, streptomycin, sulfa drugs, tyrothricin and sulfamylon); (2) improved surgical technics; (3) accelerated evacuation and transportation of the wounded and (4) processing, transportation and front line use of whole blood, plasma and blood substitutes. There is a section on psychosomatic problems affecting the foot and ankle. There is a section on manipulation and the author gives eighteen general precepts on manipulative surgery. As many problems of physical medicine concern the foot and ankle this book is of great interest to all physicians interested in physical medicine.

PHYSICAL MEDICINE ABSTRACTS

Human Pathologic Anatomy of Ionizing Radiation Effects of the Atomic Bomb Explosions. Elbert Decoursey.

Military Surg. 102:427 (June) 1948.

The detonation of an atomic bomb is said to result in rays that cover the entire length of the spectrum. The intensity of the thermal radiation was so great in Nagasaki that there were flash burns on such things as wood, oranges, tile and people. Such thin things as leaves, blades of grass, or clothing acted as filters and offered protection to their shadows.

Ionizing radiation, the agent which makes the atomic bomb unique among all other weapons, not only contributed to the morbidity and mortality but also by hindsight contributed in Japan a biological experiment of unprecedented scope. Thousands of humans, because of distances from the source and because of various shieldings received radiation varying from very small amounts to several times the lethal dose.

The Optimal Physical Therapy for Rheumatoid Arthritis. Ernest Stengel.

New York State J. Med. 48:1028 (May 1) 1948.

Proper physical therapy is an important part of the management of rheumatoid arthritis. Ion transfer, using magnesium sulfate, sodium salicylate, histamine and mecholyl, represents the optimal form of physical therapy for the treatment of rheumatoid arthritis. There is a definite contraindication of certain physical therapy procedures of which the sedimentation rate is a valuable indicator. There is a certain order of procedure when administering drugs concurrently with physical therapy.

Early Ambulation in Abdominal Surgery. F. M. Simmons Patterson, and J. J. Richardson.

North Carolina M. J. 9:301 (June) 1948.

Until recently the authors tried to get their patients to walk between the eighth and forty-eight postoperative hours, but they have now come to feel that early ambulation is of limited value unless the patient actually walks before twenty-four hours have elapsed.

If the operation has been a minor one, the patient is asked to lie on his side near the edge of the bed, assistance being given if necessary. The head of the bed is then elevated to a high backrest position and the patient is allowed to dangle his feet. If vertigo ensues, the procedure is repeated later until this is overcome.

After the patient has sat with his feet dangling for a few minutes, he is assisted to his feet, permitted to walk ten to twenty paces with assistance and then allowed to remain in a chair for fifteen to twenty minutes. In addition to ambulation, the authors insist from the start that the patient be active while in bed. He is encouraged to take deep breathing exercises, to change position at least once an hour, and to dorsiflex the feet at least a thousand times each day.

A series of 504 cases of abdominal operations in which early ambulation was employed is reported. There was no mortality. The incidence of postoperative complications, with the possible exception of phlebitis, was decreased markedly Except for those conditions which demand bed rest, the authors have found no contraindications to early ambulation and recommend its use without qualification.

Electronic Apparatus for Immediate Visual Recording of Pulse Rate. W. Rotheram.

Roy. Soc. Med. 41:283 (May) 1948.

A more scientific approach to the study of electric changes in contracting muscle became possible with the advent of Lippman's capillary electrometer and later Einthoven's string galvanometer. The moving parts of these instruments were sufficiently light to follow the rapid variations of potential. They moreover allowed records to be made so that analysis of both waveform and frequency became possible.

It is, in the case of E. M. G., too important to observe the patient personally during the actual examination and, if necessary, to modify the condition under which the examination is conducted.

It may be possible in the future to standardize recording technic and terminology to such an extent as to make this practicable but the time has not yet come.

The author thinks that this clinical application of electrophysiology has great potentialities but that the value of the contribution which it may ultimately bring to neurology will in a large measure depend on how well it is supported during its developmental stages by the tripod made of the neurosurgeon and the morbid pathologist.

Studies of the Pulmonary Circulation at Rest and During Exercise in Normal Individuals and in Patients with Chronic Pulmonary Disease. R. L. Riley; A. Himmelstein; H. L. Motley; H. M. Weiner, and A. Cournand.

Am. J. Physiol. 152:372 (Feb. 1) 1948.

Studies of cardiac output and pulmonary arterial pressure were performed using the venous catheter technic in three normal individuals and in eight patients with various types of pulmonary disease. Measurements were made at rest during

exercise on a stationary bicycle. Two of the three normal subjects showed a decrease in the mean pressure in the pulmonary artery during exercise; all showed a marked drop in pulmonary vascular resistance and a minimal increase in the work of the right ventricle during exercise. Three of the patients with chronic pulmonary disease showed a significant elevation of pulmonary arterial pressure at rest, and in all eight cases the mean pressure increased during exercise. There was either no change or an increase in the pulmonary vascular resistance during exercise, and the work of the right ventricle was invariably higher than in the normal subjects at a corresponding work level. The observations indicate that the expansibility of the pulmonary vascular bed during exercise is limited in patients with chronic pulmonary disease. Anoxia may contribute to the elevation of pulmonary arterial pressure during exercise in those patients whose arterial oxygen saturation falls. The physiologic evidence on which an estimate of disability must be based in patients with chronic pulmonary disease is extended by studies of the pulmonary circulation during exercise.

The Effect of Histamine Treatment in Diseases of the Skeletal System. Otto C. Kestler.

Med. Rec. 161:211 (April) 1948.

The author concludes that iontophoresis is still the most effective method and appears to be superior to intravenous administration. However, iontophoresis combined with intravenous or intra-articular application in a limited number of cases seems to have a promising effect.

The Magnuson-Stack Procedure for Recurrent Dislocations of the Shoulder. N. J. Giannestras.

Surgery 23:794 (May) 1948.

The multiplicity of procedures described for repair of recurrent traumatic subcoracoid and subglenoid dislocation of the shoulder is ample evidence that no procedure has yet proved completely successful. During the last few years two procedures have held out more hope for permanent reduction; one is the Bankart operation of repair of the capsule, and the other the Magnuson-Stack procedure of transportation of the tendon of the subcapulares from the lesser to the greater tuberosity of the humerus. The author is concerned with the latter procedure, and wishes to report a follow-up study of thirty-one such operations, which vary in followup from three years to one and one-half years. It is conceded that the length of time elapsed is insufficient for a complete and final analysis, but it is hoped that this report will serve as an added impetus for more bone and joint surgeons to use this procedure. It appears to be quite promising, and only by reviewing a large series of cases, at least five years after surgery can any definite conclusions be reached.

The period of absolute immobilization is three weeks. At the end of this period of immobilization active and passive exercises are instituted in the form of pendulum exercises actively, three times daily for ten minutes and gentle external rotation passively once daily by the physical therapist. Active external rotation and abduction were not instituted until the end of six weeks, at which time these motions are included in the daily exercise routine. At the end of eight weeks, the average patient has almost complete range of all motions, except for external rotation which is usually limited to about 110 degrees of the normal, the normal being between 130 to 140 degrees.

Low Back Pain — Orthopedic Aspects. W. R. Hamsa.

Nebraska M. J. 33:210 (June) 1948.

Treatment of acute low back strain consists primarily of rest and graduated physical activity. The former is obtained by recumbency on a semi-rigid mattress. The presence of any flexion contracture of the hips as indicated by a positive Ely or Ober test suggests the addition of flexion of hips and knees to flatten the usual lumbar lordosis, this may be added to any strain for comfort and hence justifies a trial. Rest on either side in similar position is allowed if comfortable. A strain not associated with nerve symptoms is seldom improved by the addition of leg traction. When used, the semi-flexed position of hips and knees is advantageous. Local heat as diathermy, infra-red radiation or hot packs afford relief and shorten convalescence. When sufficient improvement justifies change to ambulatory treatment, support by either adhesive strapping or corset is added. Activity is restricted for least three months as a recurrence may follow simple exertion, especially in persons with posture change.

Of particular importance is the equalization of leg length by adequate shoe elevation whenever necessary. Minor shortening of a leg is a common occurrence and probably causes little difficulty. However, the combination of a strain in the low back area and leg length difference prolongs symptoms due to asymetrical function.

Discussion of postural strain necessitates introduction of normal posture development and its mechanics. Posture may be defined as the relation of the center of gravity to the line of gravity. Man's posture is a result of developmental changes and functional stresses which must be interpreted as comparisons to the normal persons stance. The term "normal individual" cannot be held to a rigid formula. Normal posture is present when the relation of center of gravity to the line of gravity is comparable to that of the majority of persons. Theoretically, this line of gravity rises through or slightly anterior to the ankle, through the knee and hip joints, and then crossing the junctions of sacrolumbar, lumbodorsal, and cervicodorsal sections of the spine. Some increase or decrease from this relationship must be allowed, particularly in slender or stocky persons with normal posture.

Vegetative Hypertrophic and Atrophic Sciatic Neuralgia. V. Pitha.

Rev. Neurolog. 79:481 (July) 1947.

Pitha reports 15 cases of vegetative hypertrophic and atrophic sciatic neuralgia, a syndrome associated with hernia of the intervertebral disk and classic funicular sciatica and with certain cases of the Guillain-Barre syndrome and neuritis. This vegetative sciatic neuralgia of rheumatic origin is to be considered a new clinical entity different from that of classic sciatica (Cotugno's disease). This atrophic and hypertrophic sciatica is characterized by a certain type of pain. Except for the initial dramatic attack of pain, it is relatively mild, always tolerable, sometimes burning and occasionally diffuse, particularly in the area of the calf. The muscle group involved is severely and diffusely painful on palpation, in contrast to a mild or absent Lasegue's sign. In the initial stage of the disease there may be present occasionally the classic signs of sciatic radiculitis, and the term "total neuralgic phase of vegetative sciatica" is suggested for it; the hypertrophic type often may be associated with intense pain in the lumbar region and in the abdomen. The muscular changes occur slowly after the acute stage, and they characterize the chronic stage. There are no real disturbances of motility, and muscular weakness may occur only after a prolonged walk. The muscular changes are diffuse and involve the entire limb. The upper half of the calf is particularly affected, and hypertrophy of the thigh may be associated with atrophy of the leg in the same patient. There are no fibrillary tremors. The muscle tonus is increased in the hypertrophic form and diminished in the atrophic form. The idiomuscular excitability is mildly and regularly diminished in the hypertrophic and in the atrophic sciatica. In general there are no changes in the tendon reflexes in both forms. The course of the atrophy is a slow one, sometimes of several years' duration, but the hypertrophic form develops in several months. These muscular symptoms are to be considered as the most important clinical aspect of the direct vegetative innervation of muscles. It may be safer to explain the common sciatic changes on the basis of a vegetative pathogenesis of the muscular changes than on one of inactivity.

Study of Mechanism and Treatment of Experimental Heat Pyrexia. W. M. Daily, and T. R. Harrison.

Am. J. Med. Sci. 215:45 (Jan.) 1948.

Daily and Harrison use the term heat pyrexia synonymously with headstroke. They produced heat pyrexia in dogs, rats, and mice by exposure to high environmental temperatures. Except for differences related to the sweating mechanism, and the more rapid course of events in smaller animals, the clinical picture of heat pyrexia in animals resembles closely that seen in man. On the basis of the studies in animals, the author suggests a treatment for human subjects with heat pyrexia. If the patient is comatose, or if body temperature is above 41 C. (106 F.), he should be immersed in ice water. Milder instances may be treated by evaporative cooling. The oral temperature should be followed minute by minute during the process of cooling. At an oral temperature of about 38.5 C. (101 F.) the patient should be moved to a tub of water at about 38 C. After the body temperature has stabilized at a normal level, hydrotherapy may be discontinued. If manifestations of shock — gray skin, slow filling of blanched areas, poor filling of veins behind a tourniquet and severe hypotension — are present, infusions must be given with great caution, the venous pressure, state of breathing and breath sounds being continuously observed. Rapid digitalization probably is indicated if pulmonary edema or rising venous pressure develop. Oxygen therapy may be valuable when either peripheral failure or pulmonary edema is present. The patient's temperature must still be watched after the emergency state has passed. Attention should be given to fluid and electrolyte requirements.

Refrigeration in Treatment of Arterial Obliterations of the Extremities. G. Bickel, and J. Fabre.

Praxis 37:1 (Jan. 8) 1948.

Bickel and Fabre treated 4 patients, 3 women between the ages of 72 and 80 and 1 man, aged 80, with gangrene of the lower extremities from obliteration of the arteries, by refrigeration. Amputation was postponed because of severe cardiopathy, advanced cachexia or refusal of surgery. The extremities involved were covered with a stocking of fine wool and then wrapped with ice bags up to 10 cm. above the ischemic zone. The ice was renewed every four hours. Refrigeration was discontinued every day for three hours. The extremity treated in this manner is cooled but not frozen. The nutritive requirements of the cells are reduced by a maximum, the formation of toxins responsible for the occurrence of shock is diminished, the exudative processes are limited, proliferation of pathogenic microbes is inhibited and a pronounced anesthetic effect is produced. Pain subsided within two hours after the initiation of the treatment. There was pronounced improvement in the local condition; in 1 case the ischemic zone was reduced by 6 cm.; in another case mumification of the previously moist and septic gangrene occurred and edema and suppuration subsided. The general condition improved rapidly, temperature was restored to normal and appetite increased. Amputation could be performed after two weeks of refrigeration treatment.

Transient Hemiplegia Following Electroconvulsive Treatment. Rudolph Kaldeck

Arch. Neurol. & Psychiat. 59:229 (Feb.) 1948.

Electroshock therapy has proved its usefulness in the treatment of the major psychoses. Its value and its limitations are well established by everyday experience. However, there is still insufficient knowledge of the basic changes caused by electroshock therapy. In the case which is described here, complete hemiplegia occurred af-

ter electroshock in a young woman and lasted several days, gradually subsiding. The patient had not shown any cardiovascular disease, and neither curare nor any other drug was used.

Wound Healing in Early Ambulation. Henry P. Royster; Lillian I. McCain, and Alexander Sloan.

Surg., Gynec. & Obst. **86**:565 (May) 1948.

The recent work of Leithauser has refocused attention in this country on the advantages of early postoperative ambulation. This method of treatment has often been a source of doubt in the minds of surgeons who naturally might fear a disturbance in wound dealing, especially after laparotomy. The possibility of rupture of the abdominal wound or subsequent herniation, has long been a hindrance toward getting patients out of bed soon after an operation, despite reports which specify that in case of wound rupture, the majority of these accidents occur before the patient becomes ambulatory.

This work was designed to compare the tensile strength of abdominal wounds of a group of dogs exercised daily after operation with a similar group — closely confined. The conditions reproduced as nearly as possible those of patients treated postoperatively by bed rest and by early ambulation.

Studies of serum protein, weight change and tensile strength of the abdominal wound were performed in 26 dogs. One-half of the animals were kept inactive after operation and the others were treated by early postoperative ambulation. Comparison of the two groups is as follows: The general condition of the ambulated animals was improved over that of the controls. A significant number of animals in the ambulated group gained weight while the controls generally lost weight. The tensile strength of the postoperative abdominal wound in the ambulated group did not differ significantly from the values in the control group.

Electrographic Evaluation of Mechanical Response in Mammalian Skeletal Muscle in Different Conditions.

Neurophysiol. **11**:153 (May) 1948.

In view of the frequent use of electromyograms as indicators of muscle activity under physiologic and pathologic conditions, knowledge of the relation of EMG amplitude to the mechanical response is of considerable practical importance. The literature reveals reasons for questioning the dependability of this relation.

The relation of EMG amplitude to the mechanical response of tibialis anticus muscle was investigated under a variety of conditions in cats under Dial anesthesia with the following results: 1. Increase in frequency of stimulation, in direct load or afterload, or in the initial length, produces a marked increase in mechanical response without corresponding change in EMG amplitude under conditions of supramaximal indirect stimulation. The constance of EMG amplitude in these circumstances appears to be due to the participation of an unchanging number of motor units. 2. Increasing the intensity of submaximal stimuli results in increasing the EMG amplitude as well as the mechanical response. The magnitude of the electrical response varies with the degree of recruitment. 3. A reduction in mechanical response occurs with fatigue during indirect supramaximal tetanization and is accompanied by a corresponding decrease in amplitude of EMG. These effects involve primarily a reduction in the number of the responding muscle fibers. 4. A reduction in mechanical response without a corresponding reduction in EMG amplitude may occur at a low (twitch) frequency of indirect supramaximal stimulation. This is attributed to a reduction in contractility without a reduction in the number of active fibers. 5. An increased amplitude of EMG is regularly associated with greater mechanical response resulting from increased frequency or intensity of cortical stimulation. This is interpreted to mean increased recruitment and a concomitant rise in discharge frequency in the motor units. 6. Increasing the direct load or the initial length of the muscle in isometric contractions induced by uniform cortical stimulation likewise results in directly related increases in mechanical response and EMG amplitude. The effect of after-load is similar to that of direct load, but is less potent and occasionally lacking. The augmentation of mechanical and electrical responses by increased load or initial length seems to be based on a proprioceptive reflex drive which results in recruitment and higher discharge frequency. 7. The lack of parallelism between the mechanical and electrical response of the muscle frequently encountered and analyzed in this paper under conditions of indirect stimulation of the muscle is not found under the more physiologic conditions of cortical stimulation or voluntary effort. In the latter cases, the amplitude of the EMG and mechanogram both reflecting quantitative alterations in the physiologic innervation of the muscle.

Some Practical Aspects of Surgical Care. Robert Zollinger, and Curtis Artz.

West Virginia M. J. **44**:151 (June) 1948.

The patient who spends a great deal of time in bed prior to operation is predisposed to pulmonary embolism from phlebothrombosis of the deep veins in the legs. Early ambulation after operation will not offer sufficient protection if a prolonged period in bed at home has promoted venous stasis. Simple exercises which provide motion of the major joints will improve circulation and should be suggested if the bed rest at home is absolutely necessary. Patients become weaker in direct proportion to the duration of time that is spent in bed.

Since Leithauser's recent popularization of early ambulation in 1941, most patients are allowed out of bed on the first postoperative day. This not only improves morale but also hastens convalescence. The incidence of pulmonary and vascular complications is probably decreased; the vital capacity increases more quickly, normal bowel and

bladder function are encouraged and general postoperative disability is markedly diminished. There are a few contraindications to early rising. These include shock, cardiac insufficiency, severe anemia and cachexia, an insecure wound, presence of thrombosis, or suppuration near the wound. On the evening following operation, the patient may be encouraged to sit on the side of the bed, kick his legs and cough. Motion of the feet and legs must be encouraged. The purpose of early ambulation is defeated if the lower extremities are allowed to hang motionless over the bed or chair. The upright position promotes venous stasis in quiet legs.

After the first time out of bed, the patient is urged to be up twice a day and to walk as much as his condition permits. Many nurses and interns have no routine method of assisting patients out of bed. Every physician should familiarize himself with the proper technic of early rising and teach his principles to those responsible for the care of his patients.

Pruritus Vulvae from Rubber, Due to Allergic Sensitivity to Alkali. G. H. V. Clarke.

Brit. J. Dermat. & Syph. 60:57 (Feb.) 1948.

Clarke reports the case of a woman aged 27, in whom pruritus vulvae followed the use of rubber condoms. The irritant was traced to the presence of free alkali from potassium oleate used in the manufacture of the sheaths as a stabilizer. Soaking of the sheaths in a 0.5 per cent solution of sulfuric acid for twelve hours proved satisfactory. It is remarkable that the action of alkali on the woman's skin appears to be that of allergic sensitization rather than simple chemical damage.

Plantar Warts: Plea for Rational Treatment. C. R. McLaughlin.

Lancet 1:168 (Jan. 31) 1948.

McLaughlin calls attention to the dangers involved in treating plantar warts with roentgen rays or radium and describes a combination of curettage and diathermy, which he has found effective. He pares down the overlying horny skin until the typical bundles of the wart are clearly defined. A Volkmann spoon, the exact size of the wart, is then driven into the foot at the edge of the wart, and swept round so that the core is shelled out complete. The hyperkeratinized collar at the neck of the cavity is trimmed with scissors, and the hole converted into a "saucer." The base, which is tough, must then be scraped until smooth and repeatedly touched with a diathermy needle or an electric cautery, using a fine point with a light touch. A small wick of ribbon gauze is inserted into the cavity and the area covered with gauze and elastoplast. The patient can usually walk with care immediately; and, after the plug has been removed in forty-eight hours, there should be little discomfort. Healing is usually complete in seven to ten days. A case is presented which illustrates both the detrimental effects of roentgen treatment and the wide scope of the described procedure.

Dosage Determination with Radioactive Isotopes. II. Practical Considerations in Therapy and Protection. L. D. Marinelli; Edith H. Quimby, and G. J. Hine.

Am. J. Roentgenol. & Rad. Therapy 59:260 (Feb.) 1948.

Marinelli and associates show that when radioactive isotopes are employed either as tracers or in therapy, it is important to be able to determine the radiation dosage. Usually this cannot be measured, but when the half-life, radiation energy and biologic uptake and execretion are known it can be calculated. The paper consists of two parts. In the physical part are given mathematic formulas for dosage rates and total doses for beta ray-emitting and gamma ray-emitting isotopes, together with subsidiary formulas for safe concentration and the like. In the clinical part these formulas are accepted, and doses are considered for specific cases, for a number of isotopes of common interest. Particular consideration is given to the determination of safe tracer doses. Two extensive tables, for beta and gamma rays, respectively, give half-life, radiation average energy, fraction disintegrating per day and specific dosage data, including the safe tracer concentration, for thirty-eight isotope elements.

Isotopes and Radiation Hazards. Frank Howarth.

Lancet 6515:51 (July 10) 1948.

It is to be emphasized that, in human experimentation, there is no excuse for using an isotope technic when some ordinary chemical procedure would suffice. If the problem will not yield to a chemical approach, it is desirable before using a radioactive isotope to consider the possibilities offered by a stable isotope which can be readily detected and, with the exception of deuterium, can be administered, ad lib. without biological effect. Radiophosphorus should not be used in the treatment of patients in the reproductive period of life, or who have an expectation of life of five years or more.

Isotope work is totally unsuited to a general laboratory such as the clinical laboratory of a hospital. Unless special precautions are taken, the benches, sinks and furniture can become heavily contaminated with radioactive materials; and, if elements of long half-life, such as CO^{60}, Sr^{89}, or Zn^{65}, are used, the accumulated radiation may soon reach a dangerous level. Excellent accounts of laboratory hazards and the means for reducing them have been given by Sullivan and in some textbooks on radium.

Those intending to employ radioactive isotopes for clinical purposes should make contact with the isotope section of the Medical Research Council, where advice from experts is readily available.